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Conflict and Priority in Late Sixteenth-Century Cosmology

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INTRODUCTION

The skies of the 1570s displayed two astonishing phenomena: the outburst in 1572 of an unexpected new star in Cassiopeia and the appearance in 1577 of a brilliant new comet, whose tail stretched across Capricorn. Over half of the astronomical titles[1] produced by learned authors in this decade sought the meaning of these wondrous apparitions or "blasing starrs," and for many years historiography mirrored this attention. Until recently, questions regarding the arrangement of the planets have received less notice, mostly because such themes are absent from published titles in the 1570s.[2] And, indeed, not until 1588 did a contemporary book address both the heliocentric cosmology and the recent appearances. Tycho Brahe's *De mundi aetherei recentioribus phaenomenis* scrupulously assembled observations from all over Europe relating to the flaming object that had appeared in 1577, and amidst its abundance of calculations, tables and triangles, it presented the comet as an "aetherial phenomenon" rather than an earthly exhalation. However, somewhat abruptly and mysteriously in chapter 8, Tycho introduced a geoheliocentric planetary arrangement wherein "everything agrees most fittingly with the celestial appearances," and he recommended it against the Copernican alternative, which, although "it nowhere offends the principles of mathematics, yet it throws the Earth, this lazy, sluggish body, unfit for motion, into a motion as swift as the aetherial torches."[3] How and why was a new cosmology introduced in the context of these prodigies of the aetherial realm? Was it simply a matter, as the popular histories have it, that the Comet of 1577 had smashed the crystalline spheres?

---

[1] We have counted in J. LaLande's *Bibliographie astronomique* (Paris, 1803) all literature published for the first time in this decade.

[2] But see Robert S. Westman, "Three Responses to the Copernican Theory: Johannes Praetorius, Tycho Brahe, and Michael Maestlin," in Robert S. Westman (ed.), *The Copernican Achievement* (Berkeley and Los Angeles, 1975), pp. 285–345 and "The Astronomer's Role in the Sixteenth Century: A Preliminary Study," *History of Science*, 18 (1980), 105–47; Christine Jones, "The geoheliocentric planetary system: its development and influence in the late sixteenth and seventeenth centuries," PhD dissertation, Cambridge University, 1964, subsequently published unchanged as Christine Jones Schofield, *Tychonic and Semi-Tychonic World Systems* (New York, 1981); Victor Thoren, "The Comet of 1577 and Tycho Brahe's System of the World," *Archives Internationales d'Histoire des Sciences*, 29 (1979), 53–67; K.P. Moesgaard, "Copernican Influence on Tycho Brahe," pp. 31–55 in Polska Akademia Nauk, *Studia Copernicana*, 5 = *Colloquia Copernicana I* (Wroclaw, 1972), volume reprinted as Jerzy Dobrzycki (ed.), *The Reception of Copernicus' Heliocentric Theory* (Dordrecht, 1973); Robert S. Westman, "The Comet and the Cosmos: Kepler, Maestlin and the Copernican Hypothesis," *ibid.*, pp. 7–30, and "Michael Mästlin's Adoption of the Copernican Theory," pp. 53–63 in Polska Akademia Nauk, *Studia Copernicana*, 14 = *Colloquia Copernicana IV* (Wroclaw, 1975); Edward Rosen, *Three Imperial Mathematicians: Kepler Trapped Between Tycho Brahe and Ursus* (New York, 1986); Nicholas Jardine, *The Birth of History and Philosophy of Science: Kepler's* A defense of Tycho against Ursus *with essays on its provenance and significance* (Cambridge, 1984); Owen Gingerich, "Tycho Brahe and the Great Comet of 1577," *Sky and Telescope*, 54 (1977), 452–58 and "Dreyer and Tycho's World System," *ibid.*, 64 (1982), 138–40 (both reprinted in *The Great Copernicus Chase* [Cambridge, 1989]).

According to a prevalent scholarly view of sixteenth-century cosmology, Tycho's world system was an obvious middle option that permitted astronomers to steer a safe course between the late medieval Ptolemaic universe of nested eccentric spheres and Copernicus' sun-centered cosmos. Here we propose to examine a body of new evidence that casts doubt on the theme of inevitability in the accepted story. If, as some maintain, the Tychonic arrangement was so obvious, then why did it take over forty years after the publication of Copernicus' *De revolutionibus* for the system to be introduced? Indeed, why, after the first hint of its possibility, did it take Tycho over a decade to come to grips with certain physical difficulties of the system? Was the development of "Tycho's system" really inevitable?

One answer to these questions lies in a study of the less visible community of which Tycho was a part. That community consisted of a small, elite network of academic and court astronomers located in several major cities of the German Hapsburg realms with links to Tycho's island fiefdom of Hven and to humanistic circles elsewhere in Europe. Evidence that we have been uncovering for more than a decade reveals that during the 1570s and '80s this group was privately glossing, clarifying, and criticizing Copernicus' *De revolutionibus*. These marginal footprints, residues of a once intense discussion, indelibly record a particular community's practices of reading and construing an astronomical text. Furthermore, as we shall see, it was in the context of such communal study that a notion of personal discovery and priority emerged, closely associated with feudal prerogatives of honor.

For some time we had wondered why an apparently obvious source, a richly annotated copy of *De revolutionibus* identified as Tycho's now in the Clementinum in Prague, had played such a small role in the analysis of his thought. This question became especially pressing some years ago when we discovered several other copies of Copernicus' book annotated in the same hand, and which included extraordinarily interesting diagrams of a semi-Tychonic system. In the course of our researches we eventually found that these precious Copernican volumes had been annotated not by the great Danish instrument builder and observer, as we had originally thought, but by a little known, wandering mathematician, Paul Wittich

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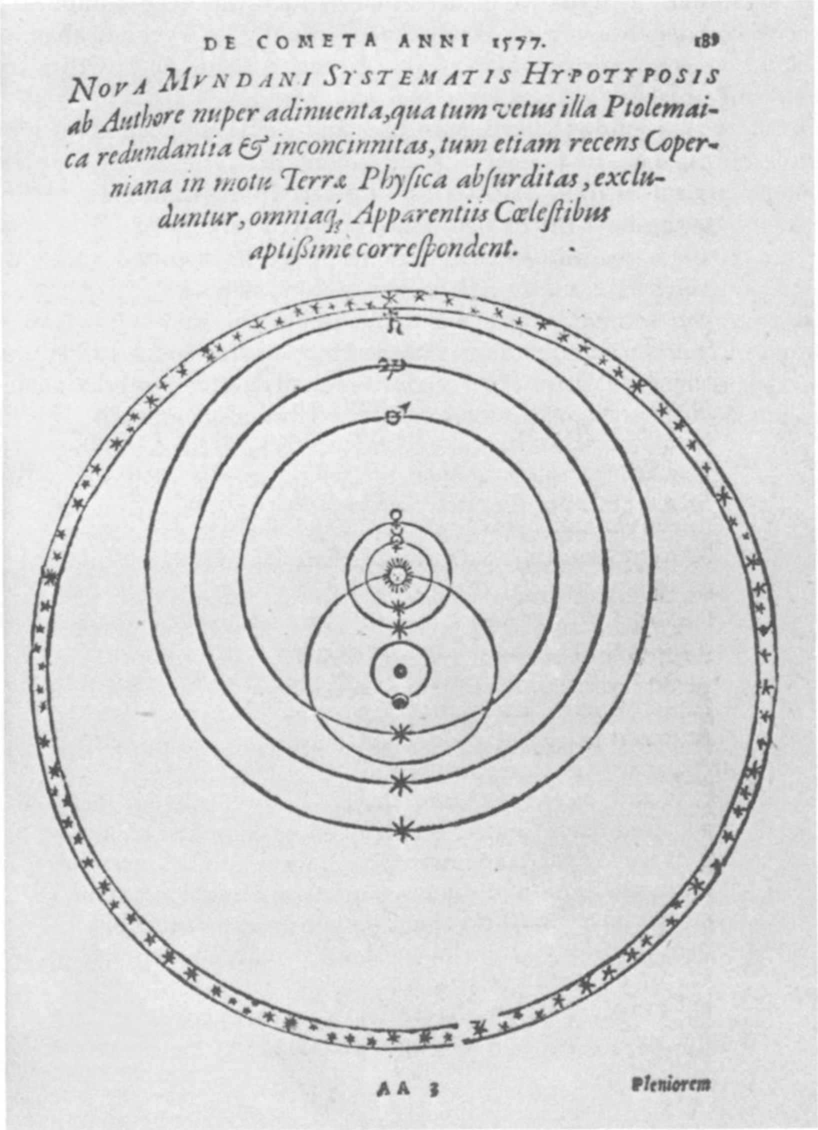
[3] Tycho Brahe, *De mundi aetherei recentioribus phaenomenis* (Hven, 1588), in J.L.E. Dreyer (ed.), *Tychonis Brahe opera omnia*, IV, 156:16–18. For a translation of the pertinent part of chapter 8, see Marie Boas and A. Rupert Hall, "Tycho Brahe's System of the World," *Occasional Notes of the Royal Astronomical Society*, 3 (1959), 257–63. Dreyer's 15-volume edition (Copenhagen, 1913–1929) will hereafter be cited as *TBOO*. Another reference, as yet unpublished, that will be cited by short title is *Census*, that is, Owen Gingerich, *An Annotated Census of Copernicus' 'De Revolutionibus' (Nuremberg, 1543 and Basel, 1566)*.



DE COMETA ANNI 1577. 189

Nova Mvndani Systematis Hypotyposis ab Authore nuper adinuenta, qua tum vetus illa Ptolemaica redundantia & inconcinnitas, tum etiam recens Copernicana in motu Terræ Phyſica abſurditas, excluduntur, omniaq; Apparentiis Cœleſtibus aptiſsimè correſpondent.

AA 3 Pleniorem

Fig. 1. The Tychonic System from *De mundi aetherei recentioribus phaenomenis* (1588), p. 189.

of Wratislavia. Once convinced of this reattribution, we proceeded to reconsider our various earlier accounts. The diagrams and notes were not Tycho's, but somehow they were connected with his work. Indeed, the more we found, the more we realized that Wittich was deeply implicated in the web of debate and controversy that eventually led Tycho to abandon the solid spheres and to construct an alternative cosmology with interpenetrating spheres.[4]

The story that follows is a complex one, and we have wrestled for some years with the task of telling it in a fashion that reflects our own excitement as some of these discoveries unfolded. In the first major section we shall describe how the earlier attribution to Tycho came about, how we unscrambled this misidentification, what we have found about the life of Paul Wittich, and how Tycho pursued Wittich's library with final success. In the second section we shall discuss the salient features of Wittich's Copernican annotations and their relationship to the earlier ones by Erasmus Reinhold. In the third section we shall describe the relationship between Wittich's systematic notes and Tycho's own struggles to establish his priority in reordering the heavens. We reserve for a further publication Wittich's discovery of the so-called "prosthaphaeresis method" of trigonometrical computations and their direct connections with John Napier and logarithms.

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[4] The material may also help us incidentally to understand better Copernicus' reluctance to stop at the geoheliocentric position; see Noel M. Swerdlow, "The Derivation and First Draft of Copernicus's Planetary Theory," *Proceedings of the American Philosophical Society*, 117 (1973), 423–512.

I. The Libraries of Tycho and of Wittich

IA. The Misleading Attribution of the Copernican Annotations

In the Clementinum in Prague there is a richly annotated *De revolutionibus* marked in the hand of a Jesuit librarian in 1642 "Ex Bibliotheca et Recognitione Tichoniana." The importance of this copy was apparently not brought to widespread scholarly attention until 1901, when the mathematician F.J. Studnička, president of the Czech Academy of Sciences and an enthusiastic historian of science, pointed out in his *Prager Tychoniana* that this was a Tychonic item of the highest importance, "for one will not again find a Copernicus glossed by a Brahe!"[5] Subsequent scholars generally agreed with this evaluation,[6] with the conspicuous exception of J.L.E. Dreyer, who passed over it in silence when editing the monumental *Tychonis Brahe Opera Omnia.*

In anticipation of the Copernican quinquecentennial celebrations there appeared in Prague a facsimile of this well-annotated book.[7] In the associated materials, labeled *Nicolai Copernici De revolutionibus orbium coelestium libri sex (Editio Basileensis) cum commentarius Manu scriptis Tychonis Brahe,* the editor, Zdeněk Horský, inquired "How can we guarantee that the commentary to Copernicus' work is really by Tycho Brahe's hand?" Having raised these doubts, Horský went on to quell them. He cited the old tradition, examined the nature of the notes, especially the references to five of Tycho's contemporaries, and concluded that the hand was "essentially . . . like the writing in well-known and undoubted relics of Tycho's manuscripts."

In May of 1973, in the course of a systematic survey of Copernican marginalia, Gingerich found in the manuscript section of the Vatican Library a first edition of *De revolutionibus* with extensive notes that matched the handwriting of the Prague second edition.[8] Several facts left no doubt that the same annotator was involved: the agreement of the hand, the similar placement of many of the notes, and numerous identical phrases. The most remarkable feature of the Vatican copy was a dozen manuscript leaves at the end carrying planetary diagrams that showed an evolution from a heliocentric to a geocentric system. The transition from a sun-centered to an earth-centered cosmology was marked by a small Latin note saying, "This new system of hypotheses occurred to me on 13 February 1578." Although this 1578 note produced a discrepancy with the 1583 date later given by Tycho for the genesis of his system, the disagreement seemed insufficiently compelling to doubt the attribution of the notes to Tycho Brahe.

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[5] F.J. Studnička, *Prager Tychoniana* (Prague, 1901), p. 43.

[6] B. Prusik, "Tychoniana der prager k. k. Universitäts-Bibliothek," *Mittheilungen der österreichischen Vereins für Bibliothekswesen*, 5 (1901), 199; R. Kukula, "Die Tychoniana der Prager K. K. Universitäts-Bibliothek," *Zeitschrift für Bücherfreunde*, 10 (1906–1907), 19; W. Prandtl, "Die Bibliothek des Tycho Brahe," *Philobiblion, Zeitschrift für Bücherliebhaber*, 5 (1932), 302–27; H. Slouka, *Astronomie v Československu od dob Nejstarších do Dneška* (*Astronomy in Czechoslovakia from its Early Beginnings to Present Times*) (Prague, 1952), p. 90

[7] *Nicolai Copernici De revolutionibus orbium coelestium libri sex (editio Basileensis) cum commentariis manu scriptis Tychonis Brahe* = Zdeněk Horský (ed.), *Editio Cimelia Bohemica*, XVI (Prague, 1971). This and other copies of *De revolutionibus* will eventually be described in Gingerich's *Census*. The Prague copy is designated there as 1566 Prague 1, which is in the Státní Knihovna CSR, Clementinum, shelf mark 14 B 16.

Later in the 1973 Copernican quinquecentennial year, Westman pointed out that few astronomers of the period could have written notes of such high quality.[9] Yet the absence of an owner's autograph on either the Prague or Vatican copy presented an obvious difficulty. Seeking to reinforce Gingerich's and Horský's original identifications, Westman cited and eliminated (on the basis of confirmed handwriting samples) what he believed to be all the leading candidates: Michael Maestlin, Christopher Clavius, Nicolaus Reymers Ursus, and Christoph Rothmann.

A year later Westman discovered yet another similarly annotated first edition of *De revolutionibus,* in the library of the Université de Liège.[10] The Liège copy contains notes in two hands. The annotations in the earlier, unidentified hand form a very precise copy of many of the glosses in Erasmus Reinhold's exemplar, which is today preserved in Edinburgh. The second layer of notes, similar but by no means the same as those in the Vatican copy, is in precisely the same Prague-Vatican hand.

During the 1977–78 academic year we had the opportunity for direct collaboration on these puzzling annotations while we were both in residence at the University of Cambridge. In analyzing a quite different set of marginal notes, written in 1604 in the hand of one Valentine von Sebisch, an otherwise unknown city councillor in Liegnitz, we noticed a strong similarity in content to the preceding group, and we thus inferred the existence of yet another lost or undiscovered set of Tychonic annotations, fastidiously and unimaginatively copied out by Sebisch.[11] Two weeks later, quite remarkably, Gingerich found this copy, a second edition owned by a private collector in London, with notes in the Prague-Vatican-Liège hand.[12]

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[8] In *Census*: 1543 Vatican 1 = Biblioteca Apostolica Vaticana, shelf mark Ottoboniana 1902. See Owen Gingerich, "The Astronomy and Cosmology of Copernicus," in International Astronomical Union, G. Contopoulos (ed.), *Highlights in Astronomy* 3 (1974), 67–85; "Copernicus and Tycho," *Scientific American*, 229 (December, 1973), 87–101.

[9] Westman, "Three Responses" (supra n. 2), pp. 340 and 342.

[10] First reported at the History of Science Society meeting, Norwalk, Connecticut, 27 October 1974, chaired by Edward Rosen. In *Census*: 1543 Liège = Liège Université Bibliothèque, shelf mark Res MS 69C.

[11] In *Census*: 1566 Wrocaw 1 = University Library, shelf mark 363152.

The discovery of a fourth copy in this growing family brought forward with renewed insistence the perplexing question of why Tycho would have annotated so many copies. Was an amanuensis involved? Westman had entertained such a possibility as early as 1974. In a discussion before the History of Science Society he claimed that the alleged Tychonic hand did not match very well the writing on certain manuscripts of Tycho's in the Vienna Nationalbibliothek—a discrepancy that had motivated his original comparisons with the handwriting specimens of other late sixteenth-century astronomers. On the other hand, the "amanuensis hypothesis" seemed unlikely because of the intrinsic nature of the notes with their exacting placement, editorial variants, and cancels. Early in 1978, when we set about to investigate Tycho's handwriting more thoroughly, it quickly became clear that the four copies were *not* annotated in Tycho's hand.[13]

At this point a number of hitherto ignored clues converged to establish without doubt the identity of the annotator. One outstanding anomaly concerned the *De revolutionibus* owned and annotated by John Craig.[14] Craig's book included notes and diagrams obviously copied directly from both the Liège and Vatican books, yet there was no record that he had ever met Tycho. Craig was personal physician to James VI of Scotland, and possibly he had accompanied the Scottish monarch to Hven for a visit of several hours on 20 March 1590, but such a brief state visit would hardly have allowed time for a substantial copying of annotations.[15] Indeed, Craig's copied marginalia provided the single most pivotal piece of evidence for reattributing the putative Tychonic note to another, but virtually unknown, sixteenth-century mathematical astronomer. On f. 82v, where the Liège annotator wrote "Cum M. M. Praecessionis Exquisitior a me inventus sit . . ." ("When the mean motion of the precession was more accurately found by me . . ."), Craig has written "Cum M. M. Praecessionis exquisite a M. Witt inventus sit . . .") ("When the mean motion of the precession was accurately found by M. Witt . . .") In the late 1570s Craig had received private instruction at Frankfurt an der Oder from one Paul Wittich of Wratislavia.[16]

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[12] In the hands of Col. Roman Umiastowski (1893-1982); subsequently the volume was donated to the Wroclaw University Library, where it joins the Sebisch copy; in *Census*: 1566 Wroclaw 2.

[13] We tried first the handwriting sample in F.I. Studnička, *Tychonis Brahe Triangulorum planorum et sphaericorum praxis arithmetica* (Prague, 1886), but quickly realized this to be spurious when we found Dreyer's note in *TBOO*, I, 315–18, in which he discusses Tycho's hand. Eventually we used Vienna National Library MS 10686.84 for comparison.

[14] In *Census*: 1566 Edinburgh 3 = University Library, shelf mark Dd.3.44.

[15] Tycho's meteorological log book, in which he regularly noted the comings and goings of astronomers, mentions only "Rex Schotiae venit mane H. 8. abij[t] H. 3." *TBOO*, IX, 83.

[16] Concerning Craig's career, see Dreyer, *TBOO*, IV, 515–18; for Frankfurt an der Oder, see Bauch, infra n. 28.

Our reattribution of the Prague-Vatican-Liège-London notes to Paul Wittich soon became secure, resting not only on strong circumstantial evidence from other annotated copies of *De revolutionibus*, but also on a comparison of one of the rare authenticated specimens of Wittich's writing, in Tycho's book of comet observations.[17] For the nights of 21–26 October 1580, there are five pages of observations made in the same hand that is found in the four Copernicus volumes, followed by an affidavit written by Jacob Monaw (1546–1603), Wittich's fellow townsman (see Figure 2):

> These pages designated with the letters ABCDE, I recognize to have been written in the hand of the late Paul Wittich, which is very well known to me, and so I testify to this in my own writing, which I left at Prague with the magnificent and noble lord Tycho Brahe on 23 October 1600.
>
> Jacob Monaw
> with my own hand.

But who was this "Master Witt" of Wratislavia?[18]

IB. Master Paul Wittich

In the recent era of the *Dictionary of Scientific Biography*, it is easy to become complacent about the biographies of minor figures. When we sat down to reconstruct Wittich's life, however, we soon discovered that even standard information about his birth, death, and travels was unreliable.[19] Even more significantly, we were struck by the fact that Wittich's achievements and reputation have been known largely through the phrases of Tycho Brahe. Often praising Wittich in his letters as "the most illustrious mathematician of Wroclaw," the egotistical and aristocratic Brahe actually saw Wittich as a subordinate—the way in which he viewed most of those who associated with him in his astronomical pursuits, (although Wittich's social position was clearly higher than that of Tycho's regular assistants).[20]

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[17] In Tycho's Comet Observations book, Royal Library, Copenhagen, GKS 1826 4°, ff. 56–58; "Cometa anni 1580" in *TBOO*, XIII, 315–17. Monaw's note of 23 October 1600 is at the bottom of f. 56v, *TBOO*, XIII, 316.

[18] In letters and on maps of the late sixteenth century the names Wratislavia and Breslau were both used for what is now the city of Wroclaw.

[19] J.L.E. Dreyer, *Tycho Brahe* (Edinburgh, 1892; reprint, New York, 1963), p. 121; Kurt Vogel, "Wittich, Paul," in Charles C. Gillispie (ed.), *Dictionary of Scientific Biography*, XIV (New York, 1976), pp. 470–71; Rudolf Wolf, *Astronomische Vierteljahrsschrift der Astronomischen Gesellschaft*, 17 (1882), p. 129; Edward Rosen, "Was Copernicus's *Revolutions* Annotated by Tycho Brahe?" *Papers of the Bibliographical Society of America*, 75 (1981), 401–12. Note Gingerich's reply, *ibid.*, 76 (1982), 473–78.

[20] "[P]raestantis Mathematici," *Astronomiae instauratae progymnasmata*, *TBOO*, III, 6:23; "insignis Mathematicus," *Astronomiae instauratae mechanica*, *TBOO*, V, 155:24; "hominem ob ingeniosam in Mathematicis . . . solertiam," *Epistolae*, Brahe to Rothmann, 20 January 1587, *TBOO*, VI, 89:18; "quidam Vratislaviensis non vulgaris Mathematicus," *De mundi aetherei recentioribus phaenomenis*, *TBOO*, IV, 374:9. In the presentation copy of this book from Tycho to Johannes Praetorius (shelf mark 461816 in the Wroclaw University Library), Praetorius has noted "Paulus Wittichius" in the margin at this reference. Although we have been unable to

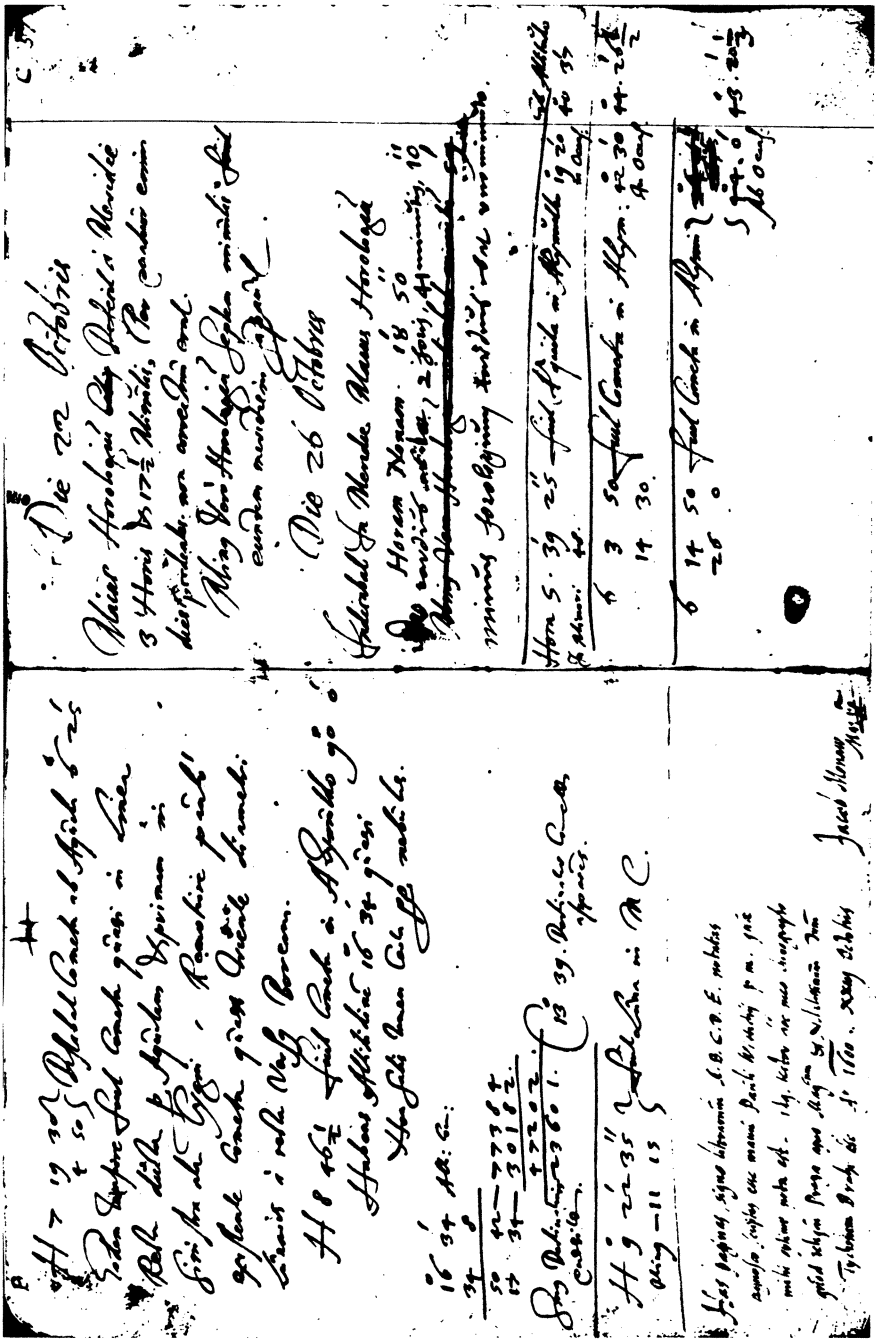

Fig. 2. Tycho's Comet Observation Book for 1580, ff. 56v-57, with Wittich's handwriting on the left and Brahe's on the right. The note in the lower left, written by Jacob Monaw, attests to Wittich's hand. (Courtesy of the Royal Library, Copenhagen.)

But Tycho's perceptions, to which we shall return shortly, say more about himself than they do about Wittich. As we searched university matriculation lists and tracked down untapped collections of correspondence in Prague, Wroclaw, Esztergom, and Oxford, we discovered that others who came in contact with the Wroclaw scholar spoke of him, almost always admiringly, as a man of notable geometrical and astronomical skills. Well born, and probably well off, Wittich was an enigmatic character whose roots remain mostly obscure. But a hitherto unknown letter from Andreas Dudith to Johannes Praetorius, written soon after Wittich's death, suggests that Wittich was already associated by family ties to the Wittenberg astronomical tradition:

> Wittich said that the *Epitome of Copernicus* was written by the author himself; he received it from his uncle, a well known physician and mathematician of this city, named Balthasar [Sartorius] whose many letters to Rheticus you were able to see at Rheticus' house. I am surprised that Rheticus did not show us this *Epitome*, which the doctor [i.e. Sartorius] is likely to have received from him; the book is not printed but is written in Wittich's hand; it is in quarto; it has 14 folios whose gatherings, as they call them, make four.[21]

The book described is clearly Copernicus' *Commentariolus*, the very first formulation of his heliocentric theory, and the setting shows that Wittich's astronomical connections reached through his uncle to Rheticus himself. In addition, Rheticus, who had been Copernicus' only disciple, corre-

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establish Wittich's social position with precision, several factors suggest that he was well off: he owned four copies of Copernicus' *De revolutionibus*, which was a rather expensive book; the obituary in Appendix II places him among contemporaries of considerable status; and he had important family connections. Nevertheless, when he departed from Hven to collect a legacy, he "readily obtained the opportunity to leave" from Tycho (Brahe to Rothmann, *ibid.*, line 28).

[21] Dudith to Praetorius, 12 February 1589, Esztergom, p. 97 (see below, n. 36): "Epitomen Copernici ab ipso auctore scriptam fuisse dicebat Wittichius, acceperat eam ab avunculo suo, Medico et Mathematico huius Urbis eximio D. Balthasare: cuius non paucas ad Rheticum epistolas videre apud ipsum Rheticum potuisti. Illud miror, Rheticum non ostendisse nobis hanc epitomen: quam verisimile est hunc Doctorem ab illo accepisse, non est unquam impressus liber, manu Wittichii scriptus, est in 4°, habet folia 14 qualia unus arcus ut vocant conficit 4." This is the earliest known citation in which the author of the *Epitome* or *Commentariolus* is identified. We are grateful to Prof. L. Szczucki for pointing out this letter and furnishing a transcription, and to him and Prof. J. Dobrzycki for identifying Balthasar Sartorius. See their forthcoming article, "On the Transmission of Copernicus's *Commentariolus* in the Sixteenth Century," *Journal for the History of Astronomy*, 20 (1989), pp. 25–28. A Balthasar Sartorius from Oschatz just east of Leipzig matriculated at Leipzig in 1555, became magister there in 1556, ThB in 1567, and ThD in 1573 (Georg Erler, *Die Matrikel der Universität Leipzig*, vol. 3 [Leipzig, 1902], p. 745). The same source indicates that he was a pastor and superintendent at Grimmen in Pomerania and then councillor and praeceptor to Duke Friedrich Wilhelm of Saxony; whether this same person is the medical doctor of Wroclaw 16 years later is not certain. Fragments of two letters from Sartorius to Rheticus written in 1555 and 1556, in the Camerarius Collection in the Munich State Library, have been transcribed in L. Birkenmajer, *Mikołaj Kopernik* (Cracow, 1900), pp. 600–601. E. Zinner, *Verzeichnis der astronomischen Handschriften des deutschen Kulturgebietes* (Munich, 1925), lists as item 9322 a "Sterndeutung" MS in the Vienna National Library, MS 10678, by B. Sartorius; the item is in a presentation hand that may or may not be by Sartorius himself.

sponded with a Johannes Wittich in Wroclaw, who may have been another of Paul's relatives.[22]

We now also know that Wittich became a kind of itinerant humanistic tutor to men who valued and practiced astronomy in a variety of contexts. In an age of wandering scholars, like the more famous Bruno and Paracelsus, Wittich was not an unusual social type. His circuit took him through a web of humanistic circles and universities in the Hapsburg lands and the German principalities. His routes fan out from his home city of Wroclaw west to the Silesian town of Görlitz; then, a hundred miles beyond it, to the major university centers of Leipzig and Wittenberg, schools that attracted many students of Silesian origin; then, south to the great Hapsburg Court at Prague; later to the academy of Altdorf, near Nuremberg; and finally, to yet another university town, Frankfurt an der Oder.

We first discover Wittich at Leipzig, where he matriculated in the summer of 1563.[23] A survey of sixteenth-century scholars at German universities shows that the typical age at matriculation was 17 years, which would place his birth around 1546; hence he was a close contemporary of Tycho Brahe's (born 1546), and rather older than previous biographers have assumed.[24] A few years later, in June 1566, Wittich matriculated at Wittenberg, a type of transfer not at all uncommon among university students of those days.[25] In fact, Tycho Brahe himself first matriculated at Leipzig in 1562 (as a 15-year-old) and later appeared at Wittenberg in 1566 and again in 1570 (although without actually matriculating there until he brought his sons along in 1598).[26]

In 1576, when he matriculated at Frankfurt an der Oder,[27] Wittich met John Craig (1553?–1620), a Scottish teacher whom he later described as "knowledgeable about mathematics and philosophy."[28] It was then that

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[22] In a letter to Hans Crato in Wroclaw in 1554, Rheticus mentions a Wittich in a context to suggest that the person is in Wroclaw; K.H. Burmeister, *Georg Joachim Rhetikus, 1514–1574*, vol. 3 (Wiesbaden, 1968), p. 122, identifies him as Johannes Wittich from Weimar, a student at Jena and Vienna, and of Crato's, later a medical doctor in Sangerhausen and Eisleben, and finally palace and state doctor in Arnstadt. A Johannes Wittich from Weimar indeed matriculated at Jena in 1553 according to Georg Mentz, *Die Matrikel der Universität Jena*, vol. 1 (Jena, 1944), but we cannot confirm Vienna in the Vienna matriculation; the source of Burmeister's information is not clear.

[23] Georg Erler, *Die Iüngere Matrikel der Universität Leipzig 1559–1809*, vol. 1 (Leipzig, 1909), p. 513c.

[24] See Owen and Miriam Gingerich, "Matriculation Ages in Sixteenth-Century Wittenberg," *History of Universities*, 6 (1987) 135–37.

[25] *Album Academiae Vitebergensis ab A. Ch. MDII usque ad A. MDCII*, vol. 2 (Halle, 1894), p. 103b.

[26] For Wittenberg, *ibid.*, p. 454a, and for Leipzig, Erler, *Die Iüngere Matrikel* (supra n. 23), p. 43c. For 1570, see Norlind, *Tycho Brahe* (infra n. 63), p. 26.

[27] Ernst Friedlaender, (ed.), *Aeltere Universitäts-Matrikeln*, 1, *Universitäts Frankfurt a. O. = Publicationem aus den k. Preussischen Staatsarchiven*, 32 (Leipzig, 1887), p. 253a. There is a curious italic note (indicating a later addition), *Rudolfi II imperialis mathematicus*. Craig's own matriculation is found on p. 228b.

[28] Reported by Dudith in a letter to the German historian Reiner Reineccius, 12 September 1581, Wroclaw University Library MS 1949/594, f. 23 = Rhedigeriana XLI. For more details

Wittich must have transmitted his ideas about an ingenious method—called prosthaphaeresis—for reducing the tedious labors of multiplying large numbers.[29] Craig copied Wittich's prosthaphaeresis method into the blank spaces of his own volume of *De revolutionibus* and later, when he returned to Edinburgh to become court physician to James VI, discussed it with John Napier, the man generally credited with the invention of logarithms.[30] A few years after Wittich died, Craig praised him saying, "If you require mathematical demonstrations, when others do not suffice for the occasion, then I turn to those of Wittich."[31]

It was during the 1570s, as Wittich peregrinated from place to place, that he made occasional astronomical observations and busily added marginal annotations into his copies of *De revolutionibus*. Observations from 1572 and 1574 are mentioned in the Vatican copy.[32] In 1577 Wittich was one of many who observed the great comet, but from where we do not know. It is tempting to suppose that Wittich observed the comet with Bartholomew Scultetus (1540–1614), an astronomer who eventually became a well-placed public official in Görlitz, because Tycho groups Scultetus and Wittich together in discussing and criticizing the parallax method that they applied to the comet. Wittich may have met Scultetus at Leipzig, and again at Wittenberg. Wittich never published his comet observations but lent them to a mutual friend in Prague—the court physician, Thaddeus Hagecius (1525?–1600).[33] In general, he did not get high marks for his observing. Tycho remarked on the lack of accuracy in his lunar eclipse observations, although "in his treatment of geometry and trigonometry he was more agile and successful"[34]; independently Christoph Rothmann (observer for Wilhelm of Cassel) noted in one of his manuscripts that Wittich had poor eyesight and should have stuck to geometry.[35]

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on Craig's career at Frankfurt an der Oder, see Gustav Bauch, *Das aelteste Decanatsbuch der philosophischen Facultaet an der Universitaet zu Frankfurt a. O.* (Breslau, 1901).

[29] Martha List and Volker Bialas, "Die Coss von Jost Bürgi in Radaktion von Johannes Kepler," *Nova Kepleriana*, Neue Folge Heft 5 (Bayerische Akademie der Wissenschaften, Mathematisch-naturwissenschaftliche Klasse, *Abhandlungen*, Neue Folge, Heft 154), (Munich, 1973); J.L.E. Dreyer, "On Tycho Brahe's Manual of Trigonometry," *Observatory*, 39 (1916), 127–31; Rudolf Wolf, "Geschichte der von Tycho, Wittich und Bürgi als Vorläuferin der Logarithmen erfundenen Prostaphaeresis," *Astronomische Mitteilungen*, 31–40 (1872–76), Nr. 32, pp. 55–67; A. v. Braunmühl, "Zur Geschichte der Prostaphaeretischen Methode in der Trigonometrie," *Abhandlungen zur Geschichte der Mathematik*, 9 (1899), 2–29; Victor Thoren, "Prosthaphaeresis Revisited," *Historia Mathematica* 15 (1988), 32–39.

[30] F. 74 in Craig's *De revolutionibus*; in *Census*: 1566 Edinburgh 3 (supra n. 14). The report that Craig informed Napier is in Anthony à Wood (1632–95), *Athenae Oxonienses* (London, 1815), pp. 491–92 and quoted in Florian Cajori, "Algebra in Napier's Day and Alleged Prior Inventions of Logarithms," in C.G. Knott (ed.), *Napier Tercentenary Memorial Volume* (London, 1915), p. 100.

[31] *TBOO*, VII, 180:42.

[32] According to *Census*, 1543 Vatican 1, the date 8 November 1572 is found on f. 57v and the date 16 September 1574 is on ff. 54 and 163.

[33] *Epistola ad Martinum Mylium in qua examinatur sententia Michaelis Moestlini et Helisaei Roeslin de Cometa Anni 1577* (Gorlitz, 1580), f. B2.

[34] Brahe to Rothmann, 17 August 1588, *TBOO*, VI, 142.

[35] Christophori Rothmanni Mathematici Observationum Stellarum Fixarum Liber Primus,

In October 1579, Wittich was again back in his home town, where we now begin to learn more consistently about his movements from the extensive correspondence of the Hungarian humanist, theologian, and church diplomat, Andreas Dudith (1533–89).[36] Formerly Bishop of Pecs, Dudith was twice married, converted to Calvinism, excommunicated and burned in effigy. By the late 1570s, under the patronage of the Polish king, he had gathered around himself a circle of erudite and wealthy men in the safe, intellectually heterodox city of Breslau. *Noster Wittichius*—as Dudith was fond of calling him—was a welcome member of this group.[37]

To Hagecius, Dudith wrote that he and Wittich were planning to observe the forthcoming eclipses (a partial solar eclipse of 22 October and a total lunar eclipse on 31 January 1580).[38] A few weeks later he wrote again, saying:

> Wittich allows neither reason nor advice, neither "prayers nor prizes" (as you say), to dissuade him from his enthusiasm for traveling. In his very pleasant company for a few days, I have felt myself enflamed for mathematical studies—in this I cannot marvel enough at how much of a beginner I am. I had made some progress a few years ago, but when Praetorius took leave of us he extinguished those little flames. Likewise, if [Wittich] leaves us, as he intends, this will also vanish.[39]

Johannes Praetorius[40] (1537–1616), a friend and frequent correspondent of Dudith's, was the first to hold the mathematics professorship at the young academy of Altdorf (near Nuremberg).

Murhardsche Bibliothek (Cassel), Folio MS Astron.5 No. 7, chaps. 3–4, esp. f. 13v, cited in Bruce T. Moran, "Christoph Rothmann, the Copernican Theory, and Institutional and Technical Influences on the Criticism of Aristotelian Cosmology," *Sixteenth Century Journal,* 13 (1982), 85–108.

[36] See Pierre Costil, *André Dudith, Humaniste Hongrois, 1533-1589* (Paris, 1935). Some letters from Dudith to Hagecius were formerly in Breslau but disappeared during World War II. Fortunately, through the good offices of Zdeněk Horský, we have been able to use a set of photostats made during the 1920s, which are described briefly by Quido Vetter, "Rapporto sulle lettere indirizzate al Dottor Taddeo Hagecius da Hayck, astronomo, medico e matematico ceko conservate a Breslavia," in *Atti del Congresso Internazionale dei Matematici Bologna 3–10 Settembre 1928,* vol. 6, (Bologna), pp. 499–501. We cite this group of letters as "Prague." Other letters from Dudith to Hagecius and a large group to Johannes Praetorius, unknown to Costil, are found in the Archiepiscopal Library in Esztergom, Hungary; these were brought to our attention by Prof. L. Szczucki, and we are grateful to L. Bartha for providing photographs of them. This codex, MS Cat. V, Tit. IV, d, will be cited simply as "Esztergom."

[37] Dudith to Hagecius, 12 October 1579 (Prague; Esztergom, p. 192): "Wittichium amare coepi"—"I am beginning to like Wittich."

[38] Dudith to Hagecius, 1 October 1579, Prague.

[39] Dudith to Hagecius, 11 November 1579, Prague: "Wittichius nullis rationibus aut consiliis, non prece, non precio, ut inquit ille, a suo peregrinandi studio abduci se patitur. Paucorum dierum consuetudine eius, mihi sane periucunda, inflammari me sentiebam ad mathematica studia, in quibus mirari satis non possum quam tyro sim. Eram aliquo usque progressus annis superioribus sed Praetorius noster abitu suo, igniculos illos exstinxerat. Item eveniet, si nos, ut constituit, hic quoque deserit."

[40] For Praetorius, see Westman, "Three Responses," (supra n. 2) and S.I. Apinus, *Vitae Professorum philosophiae qui a condita Academia Altorfina ad hunc usque diem claruerunt . . .* (Nuremberg and Altdorf, 1728), pp. 13–31.

In January, Dudith confirmed that Hagecius was one of Wittich's correspondents when he wrote that "I have received your letters, and have also read those you have written to our friend Wittich."[41] Dudith added, "I am making great efforts so that I might not only retain Wittich in this city, but that I might keep him in my house." But he did not succeed in keeping Wittich in Wroclaw continuously, for the roving mathematician packed himself up for a three-month visit to Tycho Brahe. Wittich returned from Denmark early the following year, in time to join discussions with an Oxford visitor, Henry Savile (1549–1622).[42] Dudith, writing to Hagecius in February 1581, indicates that they were studying Ptolemy, while Savile, writing the following month to Praetorius from Dudith's house, mentions also Copernicus.[43] By August, Savile had departed for Venice, and Dudith, in a letter to Henry Neville there, requests assistance in interpreting ancient and modern astronomers: "I strongly urge you to press Savile harder and more sharply to work out something for me concerning difficult points in the ancient mathematicians and about Copernicus, a man who stands comparison with the ancients or, if Wittich is to be believed, is even to be preferred to them."[44]

In the following January, Dudith mentioned to Hagecius that "Wittich, at my request, wrote more than 24 theorems on the doctrine of parallaxes, accommodated to the Copernican motion of the earth. . . . Between you and me, Savile had a low opinion of all these, and he claimed that all that had any value Wittich had taken from his friend Digges, although he didn't value Digges much either."[45] Since presumably it makes no difference whether Copernicus or Ptolemy is used to compute the parallax, perhaps Savile got the better of this argument. In any event, Praetorius wrote to Savile after Wittich's death saying, "When Wittich was with me in Nuremberg, he showed me some methods for observing parallaxes of which Tycho also makes mention and of which certain ones pertained to the theses of Copernicus, but, as he himself maintained, others applied

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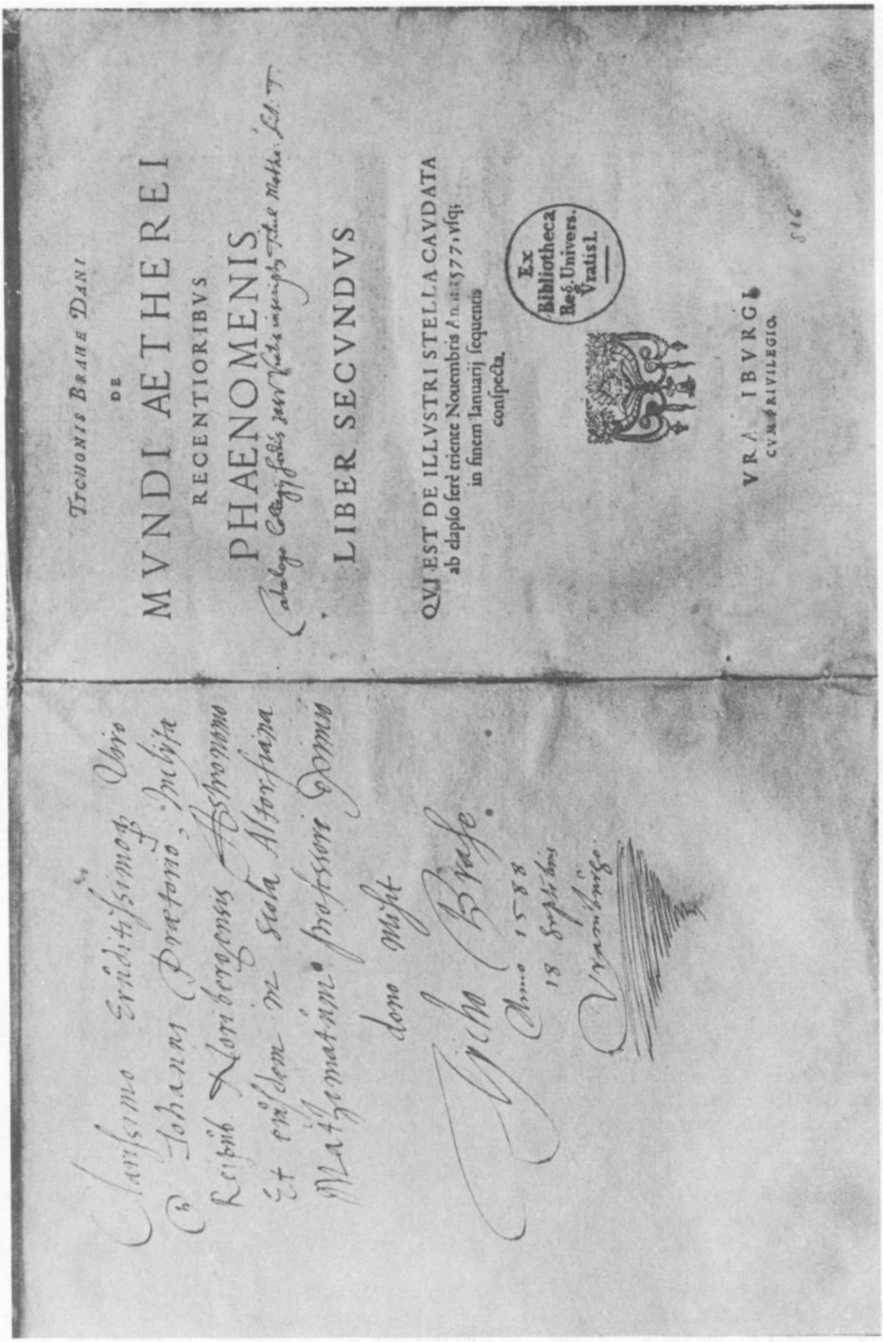
[41] Dudith to Hagecius, 29 January 1580, Esztergom, pp. 195–96; also in Prague.

[42] A small fragment of Wittich's hand, otherwise unidentified, appears among a group of Henry Savile's papers in the Bodleian Library. MS Savile 47, f. 25, has under a diagram, in Wittich's hand, "Examen calculi astronomici pro Parallaxibus Cometae observati a D Taddeo Ao 1580 D 13 Octob." At the end of this gathering, f. 27v, we read "Miscellanea pleraque . . . Dudith, mea, Th. Savile, Praetorij."

[43] Dudith to Hagecius, 26 February 1581, Prague; Henry Savile to Praetorius, 7 March 1581, Bodleian Library, MS Savile 108, f. 102v.

[44] Dudith to Henry Neville, 7 August 1581, Wroclaw University Library MS 1949/594, ff. 16–16v = Rhedigeriana XXVIII; cited as Cod. Rhed. 253, no. 19, in Costil, *André Dudith,* pp. 444–45; translated in Westman, "The Astronomer's Role" (supra n. 2), 130.

[45] Dudith to Hagecius, 30 January 1582, Prague: "Wittichius, meo rogatu, ut ipse profitetur, scripsit supra 24 theoremata de parallaxium doctrina, ad motum terrae Copernicium, accommodata. . . . Ea Savile, ut omnia huius (quod inter nos dictum sit) contemnebat; et ex Digesseo suo artificiose depromta affirmabat, quae aliquid momenti haberent, etsi Digesseum quoque ipsum non magni faciebat." Savile's presentation copy from Digges is now in the Bodleian Library, shelf mark Savile Y.14.



TYCHONIS BRAHE DANI
DE
MVNDI AETHEREI
RECENTIORIBVS
PHAENOMENIS
Catalogo Collegij Soctis Jesu Vratis: inscriptus Titulo Mathe: fol. T
LIBER SECVNDVS
QVI EST DE ILLVSTRI STELLA CAVDATA
ab elapso ferè triente Nouembris An. 1577, vsq;
in finem Ianuarij sequentis
conspecta.

Ex Bibliotheca Reg. Univers. Vratisl.

VRANIBVRGI
CVM PRIVILEGIO.

816

Cariſsimo Eruditiſsimoq; Viro
Dn. Johanni Praetorio, Inclitae
Reipub. Noribergensis Astronomo
Et eiusdem in Schola Altorfiana
Mathematum professori Domino
dono misit
Tycho Brahe.
Anno 1588
18 Septembris
Vraniburgi

Fig. 3. The presentation copy of Tycho's *De mundi aetherei recentioribus phaenomenis* with his autograph inscription to Johannes Praetorius. (Courtesy University of Wroclaw Library.)

to those of Ptolemy."[46] There is further evidence that Wittich had made the acquaintance of Praetorius and that both were part of the same broader astronomical network. A note inside the back cover of Praetorius' *De revolutionibus* testifies: "The errors of Copernicus according to Thaddeus Hagecius, which I have received from a certain person (Paul Wittich)."[47]

Another of the men who came under Wittich's influence in Breslau was Duncan Liddel (1561–1613).[48] A Scot from Aberdeen, Liddel matriculated at Frankfurt an der Oder in 1579. There he became acquainted with his fellow countryman John Craig, who recommended that he should study with Wittich, and subsequently Liddel came to Breslau for a year around 1582. While there he transcribed some of Wittich's marginalia into one of his own copies of *De revolutionibus*.[49]

These details of Wittich's movements and contacts are of special importance because they help to situate the key group of diagrams from 1578 bound into the back of the Vatican *De revolutionibus*, all conceived well before he visited Tycho Brahe in the late summer of 1580. This was a particularly active time for the peripatetic Wittich, and he would have had many opportunities to discuss his planetary modeling techniques with any number of other astronomers, both before and after his visit to Hven. Thus, although the connection with Tycho was of critical importance, he was but one of several who were affected by Wittich.

Brahe and Wittich probably first met in 1566 or 1570 at Wittenberg where Wittich had enrolled in June of 1566.[50] Brahe recalled mentioning some trigonometrical notions, which then became the source of Wittich's ideas on the prosthaphaeresis method.[51] In 1580, Wittich paid a four-month visit to Uraniborg on the island of Hven. Tycho spoke of him now as an observing companion, as "a standard bearer for me in my astronomical studies."[52] Together, they observed a comet in October. This was undoubtedly a time of intense joint work because Tycho again spoke of the "sweat" of multiplying large numbers and the "tedium" that will be saved with the new method that Wittich is working on but has not yet perfected.[53] In a letter written a few years after Wittich's death, we catch a glimpse of one manner of forging theoretical conclusions on Hven:

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[46] Praetorius to Savile, 27 January 1589, MS Savile 108, f. 111v: "Wittichius, cum Norimbergae esset, mihi monstravit aliquot rationes observandi parallaxes, quarum etiam Tycho mentionem facit, earum quaedam respiciebant ad Copernici, quaedam ad Ptolemai theses (ut ipse affirmabat)."

[47] In handwritten notes in his *De revolutionibus* copies, Praetorius mentions getting certain information from Wittich, *Census*, 1543 New Haven 1 = Beinecke Library, Yale University, shelf mark QB41 +C663, and 1543 Schweinfurt = Stadtbibliothek, shelf mark 6796, f. 90 "iuxta opinionem Wittichij."

[48] For information on Liddel, see infra n. 161.

[49] See *Census*, 1566 Aberdeen 2; this volume also contains Liddel's MS copy of Copernicus' *Commentariolus*.

[50] Tycho visited Wittenberg in 1566, in 1570, and again in 1575 (Dreyer, *Tycho Brahe*, pp. 22 and 83; Norlind, *Tycho Brahe* [infra n. 63], p. 26); he does not specify on which occasion he met Wittich, but an earlier date seems more likely. Rosen gives no evidence for his date of 1575 (supra n. 19, his note 46 on p. 409), but perhaps he was copying from the chronology given by List and Bialas, "Die Coss von Jost Bürgi," (supra n. 29), p. 125.

[51] Brahe to Hagecius, 4 November 1580, *TBOO*, VII, 58:30–39. Previously this letter was the most important source of information on Wittich.

[52] Brahe to Rothmann, 20 January 1587, *TBOO*, VI, 89:13–21.

> Certainly your Wittich, whom you praise so much, was a man very skilled in mathematics. In those days in 1580 when a certain comet shone forth he was on hand with me when we were observing its appearances. He noticed that from its origin it continued to move for several days along an exact great circle on the sphere (which I actually pointed out directly to him on the surface of a globe), and he did not hesitate to conclude, even from this alone, that the comet had chosen for itself a path in the highest aether and not at all in the elementary region.[54]

Wittich left Hven around the beginning of November 1580.[55] Tycho mentioned that "when he had stayed with me a little over a quarter of a year and thought he had already acquired enough of what he wanted, he alleged that his uncle in Wroclaw had died, and that his legacy would bring him a great profit if he were there in time. Accordingly, having readily obtained permission to leave, he promised to come back within seven or eight weeks."[56] As a token of his generosity, or perhaps partly as a bribe to insure Wittich's return, Tycho, the Lord of Knudstrup, presented his Wratislavian colleague with a munificent gift: a costly copy of Apianus' *Astronomicum Caesareum*, inscribed "to a friend and fellow lover of mathematics."[57]

But rather than returning to Hven, Wittich stayed home for two or three years, associating with the Dudith circle, and the next thing that Tycho discovered was that Wittich had gone to the court of Hesse-Cassel, where he acted less like a faithful standard-bearer than as an agent of "technological espionage."[58] Landgrave Wilhelm of Cassel was, like Tycho, a practicing observer, and from a Dudith letter we learn that Wilhelm admired Wittich, but that the affection was not reciprocated.[59] Wilhelm also had in his entourage two skilled assistants: a practical mechanician named Joost Bürgi and a careful observer and theoretician named Christoph Rothmann.[60] Wittich demonstrated his own mechanical ingenuity by designing an astrolabe that still survives in Cassel.[61] It is also clear that Wittich spoke freely about his mathematical methods and about principles of instrument design that he had learned on Hven. Many of these points were recorded by Rothmann and ascribed to Wittich in a manuscript on the construction of astronomical instruments.[62]

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[53] Brahe to Hagecius, 4 November 1580, *TBOO*, VII, 58:34–35.

[54] Brahe to Craig, 1589, *TBOO*, IV, 422:22–35.

[55] Wittich's last comet observation in Tycho's record book was on 26 October (*TBOO*, XIII, 317, n. 28); Tycho returned to Hven on 28 October. The letter from Brahe to Hagecius dated 4 November 1580 (*TBOO*, VII, 58–60) was carried by Wittich, so he must have left Hven at about this time.

[56] *TBOO*, VI, 89:24–29; translated by Rosen, supra n. 19.

[57] Tycho signed the dedication to Wittich on 29 October. The inscribed copy is today in the Schaefner Collection, Regenstein Library, University of Chicago.

[58] Precisely how or when Tycho learned that Wittich had gone to Cassel is not known, especially because very few letters to or from Brahe survive for the years 1583–85. He mentions in 1587 to Rothmann (*TBOO*, VI, 89:31–34) that he deduced from a letter from Governor Heinrich Rantzau that Wittich had been in communication with the Landgrave. In any event, Wilhelm and Rothmann mention Wittich's presence in Cassel in letters of April 1586 (*TBOO*, VI, 52 and 57), apparently unaware that he had died.

[59] Dudith to Praetorius, 9 October 1584, Wroclaw University Library MS 1949/594, Rhedigeriana LXVI.

When Tycho learned what was going on at the court of his rival in Cassel, he was furious. From a variety of letters, we can gain some sense of Tycho's personality judgments. About Wittich, he quickly revealed his mistrust. Hagecius wrote to allay Tycho's "sinister suspicions" concerning "our friend Wittich," but Tycho nevertheless believed that Wittich was communicating crucial information about the design of his instruments and that he was divulging "other things" at the Landgrave's observatory.[63] To Bürgi he awarded a higher character reference: Bürgi "never presumed to claim as his own those things taken from Wittich."[64] But for another visitor at the Prince's court, named Nicholas Reymers Baer, and known to his contemporaries as Ursus (the Bear), Tycho reserved a more robust language: "savage, inhuman, scurrilous, rotten and sycophantic."[65]

Now Tycho's character descriptions must be seen against an important and unexpected turn of events. Wittich, having left Hesse-Cassel, died prematurely in Vienna on 9 January 1586 without a publication to his name and, as far as we know, without a manuscript in preparation.[66] His death decisively changed the context of authorial credit; those who profited from his instruction could publicly praise the man for his skills without reference to his work on the system of the world. Even as he passed from the scene, his ghost—and Tycho referred to it explicitly—still stalked the dark corridors of Uraniborg.[67] Two years after Wittich's death, Tycho published the famous system to which his name was forever after attached, and then, a few months later, Ursus came forth with a book containing a large, fold-out diagram and several propositions describing a new and rather similar "system of nature." Tycho placed his own diagram somewhat unexpectedly amidst a large volume devoted to the Comet of 1577,[68] labeling it "New Sketch of a World System lately invented by the Author; In which the Old Ptolemaic Gracelessness and Superfluity as well as the New Copernican Physical Absurdity of the Earth's Motion are eliminated and everything corresponds most fittingly to the Celestial Appearances."

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[60] Moran, "Christoph Rothmann" (supra n. 35), pp. 85–108; Jones, *Tychonic World Systems* (supra n. 2); Ludolf von Mackensen, *Die erste Sternwarte Europas mit ihren Instrumenten und Uhren: 400 Jahre Jost Bürgi in Kassel* (Munich, 1979).

[61] Wittich's astrolabe in Cassel is illustrated in von Mackensen, *ibid.*, p. 127.

[62] Christophori Rothmanni Mathematici Observationum Stellarum Fixarum Liber Primus, Murhardsche Bibliothek (Cassel), Folio MS Astron.5 No. 7. In addition to the references to Wittich cited by Moran, "Christoph Rothmann" (supra n. 35), he is mentioned on about 20 other occasions.

[63] Hagecius to Brahe, 1 May 1582, *TBOO*, VII, 69:34; Brahe to Hagecius, 1 July 1586, *TBOO*, VII, 108:30–34; Brahe to Rothmann, 20 January 1587, *TBOO*, VI, 89:29–34; for a later overview, see Brahe to Clavius, 5 January 1600, in Wilhelm Norlind, *Tycho Brahe, En Levnadsteckning* (*Skaansk Senmedeltid och Renässans, Skriftserie utgiven av Vetenskaps-Societeten i Lund,* No. 8) (Lund, 1970), pp. 376–77.

[64] *Ibid.*, 377:29–30.

[65] *Ibid.*, 377:24–25.

[66] Despite Edward Rosen, supra n. 19, his note 53; repeated in his "In Defense of Tycho Brahe," *Archive for History of Exact Sciences*, 4 (1981), 264 n. 50; again in his "The Earliest Translation of Copernicus" (infra n. 156), 302, his note 14; and repeated in his *Three Imperial Mathematicians*, p. 355, but silently corrected on p. 179. Rosen revised the erroneous year originally given by Johann Gottfried Galle to Rudolf Wolf (see n. 19) and copied by all subsequent writers, but he misread the date as 5 January. The source is Nicholas Henel's *Silesia togata*, Wroclaw University Library MS R 571, ff. 22–23 and also 452; in each place the date is written out fully in words, as "quinto Eidus Januarias" (9 January) and "supra mille quingentos sexto et octuagesimo" (1586). Rosen used f. 415v of another manuscript where he erroneously took the abbreviation for "Idus" as "D"; the manuscript he used but failed to cite is Wroclaw University Library MS IV.F.127, and an easily read date also appears on f. 641v of this copy. We thank Jerzy Dobrzycki for helping to locate these references.

A struggle erupted. Tycho abandoned the common Renaissance practice of praising the antiquity of new ideas.[69] Rather than situating himself in an ancient genealogy of wisdom, Tycho made his own authorial identity a matter of honor and legal expectation, a status to be protected against other claimants. As Tycho wrote in 1598:

> We have remedied [difficulties in the earlier systems] by means of a special hypothesis that we invented and worked out fourteen years ago, basing it on the phenomena. There are certain persons, of whom I know three with distinguished names [Ursus, Liddel, and Roeslin], who have not been ashamed to appropriate this hypothesis and present it as their own invention. In due course I shall, God willing, point out the occasions on which they did it, and repudiate and refute their immense impudence, and I shall demonstrate that the fact of the matter is as I say, and I shall do that so clearly that it will be impossible for impartial men to doubt or contradict me. But if they honestly admit their error, and give back to me that which is mine, then I shall bear with them, and therefore I now willingly refrain from mentioning their names.[70]

In the ensuing battle, modern in what it presaged for future scientific controversy, but still early modern in style, tone, and objectives, Tycho utterly vanquished Ursus' claims, and Wittich's name all but vanished into oblivion.

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[67] Brahe to Clavius, 5 January 1600, (supra n. 63), 377:31–22: "Vides itaque quanta iniuria non saltem me, sed et manes defuncti Witichii affecerit . . . ."

[68] Tycho explained to Hagecius, March 1592, that he had not intended to place his world system in this volume, but did so for fear of being anticipated by some plagiarist. See our translation in Section IIIB here.

[69] Daniel Pickering Walker, *The Ancient Theology: Studies in Christian Platonism from the Fifteenth to the Eighteenth Centuries* (Ithaca, 1972). On the emerging rhetoric of novelty, see Lynn Thorndike, "Newness and Novelty in Seventeenth-Century Science," in Philip P. Wiener and Aaron Noland (eds.), *Roots of Scientific Thought, A Cultural Perspective* (New York, 1957), pp. 443–57. Marie Boas Hall calls attention to "the most telling example of this fashion" of novelty in the series of copper plates showing various discoveries and published around 1580 by the Flemish artist Jan van der Straet ("The Spirit of Innovation," pp. 309–321 in Owen Gingerich [ed.], *The Nature of Scientific Discovery* [Washington, D.C., 1975]).

[70] Hans Raeder, Elis Strömgren, and Bengt Strömgren (eds.), *Tycho Brahe's Description of His Instruments and Scientific Work* (Copenhagen, 1946), p. 115; *TBOO*, V, 115; the identification of the three distinguished names has been given by Dreyer.

IC. Tycho's Attempts to Acquire Wittich's Library

To the end of his life Tycho Brahe remembered, with a curious mixture of euphoric nostalgia and unconcealed rage, the stimulating visit from Paul Wittich in the summer and early autumn of 1580. Never before had he found such congenial intellectual companionship, nor would he find someone better until the arrival of Johannes Kepler in 1600. To his Wratislavian guest Tycho opened all his secrets, or so he wrote, intimating ruefully that he had learned his lesson and would never again display his inventions so freely.[71] By the end of October of 1580, however, the ever-footloose Wittich had resolved to go back home, ostensibly to look after an inheritance; the imperious Tycho graciously granted him permission to leave after extracting a promise that he would return, but Wittich never did, and the next thing Tycho knew, Wittich was at the court of Wilhelm of Hesse, freely talking about all that was new in astronomy, whether his own or the great Dane's. Tycho remained obsessed by this outrage, and the volume of letters he published in 1596 is largely a collection designed to establish his own priorities as well as to deprecate Wittich, who in the introduction is referred to only obliquely as "a certain Wroclaw mathematician."[72]

But there was more. Tycho had learned from Wittich the first prosthaphaeresis procedure, the method whereby trigonometric identities could replace tedious multiplication and division by simple addition and subtraction.[73] He knew that Wittich had described the method in his unpublished manuscript workbook, and he knew, too, that Wittich had interestingly annotated copies of Copernicus' *De revolutionibus*. Thus, when he learned that Paul Wittich had died, he lost little time in taking steps to acquire Wittich's library.

This was not such an unusual move for Brahe. A substantial part of his correspondence deals with his efforts to obtain specific books or entire libraries. He tried to buy selected volumes from Dudith's legacy,[74] and he made overtures toward the purchase of the mathematical books from the collection of the wealthy Fugger bankers.[75] But to the end of his life he pursued the library of Paul Wittich with an uncommon perseverance.

In March of 1589 Tycho introduced two Danish barons to Hagecius, the court physician/astronomer in Prague, saying that the noblemen were acting in his name to acquire the Wittichian library.[76] Several weeks later

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[71] Brahe to Rothmann, 20 January 1587, *TBOO*, VI, 89:23–24.

[72] Introduction to *Epistolarum Astronomicarum Liber Unus* (1596), *TBOO*, VI, 25:9.

[73] Concerning the prosthaphaeresis method, see our note 29.

[74] Brahe to Monaw, 16 May 1600, *TBOO*, VII, 320.

[75] Brahe to Herwart von Hohenberg, 6/16 November 1599, *TBOO*, VIII, 201.

[76] Brahe to Hagecius, 22 March 1589, *TBOO*, VII, 166.

Hagecius responded that there were problems, that Wittich's sister, who had inherited the books, did not yet wish to sell because another party was also interested.[77] Tycho soon responded with a quotation from Virgil: "A shiftless, fickle thing is woman ever,"[78] and he expressed his hope that she might soon change her mind.

> I therefore ask you very kindly if you would do something through some reliable man living in Wroclaw, to negotiate with her in my name so that all the library and papers can be had at a fair price. I promise that I will send the money promptly, for I do not want to do anything that would cause those priceless books of that distinguished mathematician to be lost or come into the hands of people who do not value them. I especially want his Copernicus and what he wrote on trigonometry, and also other manuscripts (if any). There should be found among his books a copy of the *Astronomicum* of Apianus, which I bought for him for 20 florins and which I gave to him when he was here. I do not want it back unless it can be bought for a favorable price. But if his sister will cede that along with the others, you can keep the Apianus *Astronomicum* for your trouble, as I have another copy at hand.[79]

This would indeed have been a princely commission, for the 20 florins would exceed $2000 by today's standards.[80] Hagecius readily agreed,[81] but his faithful Wroclaw friend was on a mission to Poland, so there the matter languished. Five years later, in 1595, Brahe still continued the pursuit; he asked Hagecius whether his friend Jacob Monaw was still alive and still willing to negotiate with Wittich's sister.[82] In 1598, a dozen years after Wittich's death, at least some of the books remained with the intractable sister, but at last, there was some success: Tycho's sometime assistant, Christian Longomontanus, had seen the books, a fact duly reported to Brahe by Monaw.[83] With rekindled enthusiasm, the Danish astronomer, who had by now taken up residence in Bohemia, replied saying, "I wrote to you some time ago about buying up the Wittichian books inherited by his sister. In case it can help out in your efforts, in order to get them at a fair price, you would have my full gratitude above all if you could get the three copies of Copernicus' *On the Celestial Revolutions* that had certain annotations by himself, what he composed about triangles as well as *On the Celestial Hypotheses* if this can be found. I will pay the requested price at once."[84]

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[77] Hagecius to Brahe, 30 April/10 May 1589, *TBOO*, VII, 183:1–4.

[78] *Aeneid* IV, 569–70.

[79] Brahe to Hagecius, 1 November 1589 Old Style, *TBOO*, VII, 214–15; concerning the *Astronomicum Caesareum*, see n. 57.

[80] The modern equivalent of 20 florins is based on the special annual salary of 140 florins offered Rheticus by the University of Leipzig in 1543; a fuller account of book pricing is given in Owen Gingerich, "Copernicus" *De Revolutionibus*: An Example of Renaissance Scientific Printing," in Gerald Tyson and Sylvia Wagonheim (eds.), *Print and Culture in the Renaissance* (Newark, Maryland, 1984), pp. 55–73.

[81] Hagecius to Brahe, 1/11 June 1590, *TBOO*, VII, 251.

[82] Brahe to Hagecius, 12 August 1595, *TBOO*, VII, 371. Like Hagecius, Monaw was a distinguished physician who spent much time in Prague.

[83] Monaw to Brahe, 25 February/7 March 1598, *TBOO*, VIII, 28–29; Brahe to Longomontanus, 24 March 1598, *TBOO*, VIII, 34.

Monaw answered with the news that Wittich's sister, although quite advanced in age, had remarried and had died soon thereafter, and that the books were all mixed up. "She left one son as her heir, for whom legitimate guardians have not yet been appointed. When this is taken care of, I shall see whether anything can be done with them. The affair would have been much easier for me if Wittich's sister had lived longer; however, I shall see what can be done and what can be obtained. I hear from those who examined Wittich's books while his sister was still alive that everything is mixed up and confused in various ways, like the Sybilline Books, and I am not surprised. She was a strange woman, full of her own ideas."[85] Now by this time Tycho had in hand a list of Wittich's books as recorded by Longomontanus, who had joined him in Prague. Thus Tycho checked off the ones he wanted and sent it off to Monaw, saying that, "If, however, the guardians of the abandoned wards do not wish to sell the books separately in lots, then determine for me a fair price for the whole lot, or if it can be done, only the price of those I have designated. But if in fact they refuse altogether to sell them piece by piece, then do your best in all events so that I may borrow those which I most want, pledged on your word for a few weeks, and I shall return them in a fixed time whole and inviolate."[86] Obviously the Wittichian annotations meant a great deal to Brahe, and he keenly wanted at least the chance to copy them.

Monaw responded almost immediately, urging Tycho to relax: "It is not necessary to reply just now, because you can rest assured that in due time your wishes will be satisfied."[87] As far as the letters are concerned, this is unfortunately the end of the story. Within four months, Monaw came to Prague where he left a remarkable trace in Tycho's comet observation book, his personal verification of Wittich's hand on five pages written in October 1580.[88] A year later, Tycho himself lay dying and his own library would soon be dispersed.

How many Wittichian manuscripts and how many copies of Copernicus' book came to Prague? Probably at least the triangles manuscript and three copies of *De revolutionibus*. After all, Monaw did write to Brahe that he expected all his wishes would be met concerning the books. Perhaps Tycho guessed or remembered that Wittich had planned to write a book on planetary hypotheses, but no such manuscript has ever turned up. A second edition of *De revolutionibus* is still preserved in Prague, containing the 1642 inscription that gives its provenance as Tychonian. The Vatican first edition may well have passed through Tycho's hands to Rudolf II. The Swedish general Königsmark captured the royal castle in Prague in July 1648, and sent the Rudolphine library to Queen Christina.[89] When Christina abdicated and went to Rome, she took with her the *De revolutionibus* now in the Vatican Library, and it seems likely that the source of her copy was the loot from Prague. Although the travels of the first edition now in Liège are uncharted, it may have passed from Prague to Belgium via Jesuit mathematicians from the Low Countries who were working at the Charles University in the first part of the seventeenth century. Wittich's fourth *De revolutionibus*, a second edition, was copied in Wroclaw in 1604 or before, and probably did not go to Prague; it has recently found its way home to the Wroclaw University Library where it has joined the copy made three and a half centuries earlier.[90]

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[84] Brahe to Monaw, 31 December 1599, *TBOO*, VIII, 237:8–14.

[85] Monaw to Brahe, 14 March 1600, *TBOO*, VIII, 266:4–11.

[86] Brahe to Monaw, 16 May 1600, *TBOO*, VIII, 320:26–31.

[87] Monaw to Brahe, June 1600, *TBOO*, VIII, 325–26.

[88] See note 17 above.

We know of three other books and a manuscript that survive from Wittich's library: the splendid Apianus *Astronomicum Caesareum* mentioned by Tycho and containing his presentation inscription, now at the University of Chicago's Regenstein Library; a theological work at the Wroclaw University Library, signed "Paulus Wittich Anno 66 Id Feb" but otherwise unannotated[91]; a copy of Tycho's *De nova stella* (Copenhagen, 1573), with Wittich's annotations on the lunar eclipse section, now at the Paris Observatory[92]; and a Latin manuscript of Plato's *Timaeus*, now in Leipzig.[93] How these books traveled to their present homes is entirely unknown.

ID. The Prague Tychoniana

We are now in a position to analyze why Wittich's annotations in the 1566 Copernicus, finally acquired by Tycho, eventually were attributed to Tycho himself.

In the Clementinum in Prague there are just over 50 items that have been associated with Tycho's library.[94] Of these, 16 are in bindings stamped with his initials, T. B. O. (Tycho Brahe Ottonides), and another six are stamped with his portrait. Twelve more items have been identified by the inscribed initials TB, not counting three books with both the TBO stamped binding *and* the inscribed initials TB. Finally, there are two books presented to Tycho (by Giordano Bruno and by J.J. Scaliger), a book marked as having been bought for Tycho, and at least one with Tycho's marginalia though lacking any other identification.[95]

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[89] Christian Callmer, *Königin Christina, ihre Handschriften und ihre Bibliothekare* (Stockholm, 1977), pp. 116ff. We are indebted to Susanna Aakerman for this reference.

[90] See note 12 above.

[91] Sebastian Conradus, *Egnatius, sive Quaestura* (Basel, 1556), shelf mark 452390.

[92] Paris Observatory, shelf mark 20540.

[93] Leipzig University Library, Cod. Rep. I.4, 84. On f. 8 it bears the inscription "Thomas Schroeter Neapol. Sil. emit Breslae ex Bibliotheca M. Pauli Wittichii, Wr. Silesii, mathematici doctissimi, anno Christi 1606." See J.H. Waszink (ed.), *Timaeus a Calcidio translatus commentarioque instructus* (London and Leiden, 1962), vol. 4 of R. Klibansky (ed.), *Plato Latinus*, p. cxvi. We thank Bruce Eastwood for calling this reference to our attention and providing us with a photograph of the inscription.

[94] The principal references concerning Tycho's library are Norlind, *Tycho Brahe* (supra n. 63), pp. 333–66; Flora Kleinschnitzova, "Ex bibliotheca Tychoniana Collegii Soc. Jesu Pragae ad S. Clementem," *Nordisk Tidskritt för Bok- och Biblioteksväsen*, 20 (1933), 3–27; and Wilhelm Norlind, "Ex bibliotheca Tychoniana, Nägra anteckningar," *Nordisk Tidskritt för Bok- och Biblioteksväsen*, 13 (1926), 211–218. Our discussion is based on Gingerich's personal examination of the library in June 1978.

Clearly, the Clementinum holds a substantial fraction of Tycho's original library. However, his holdings did not go there en bloc, because this group can also be divided into those inscribed into the catalogue of the Jesuit College in Chomutov (generally either in 1645 or 1671–73), those inscribed into the catalogue of the Jesuit College in Prague (in 1642), plus a small group with other provenances. (A few items from Tycho's library are today found in still other locations.) Of the 23 items marked "Collegii Caesarei Soc[ieta]tis Jesu Pragae Anno 1642" (or slight variants), 17 also include the inscription "Ex Bibliotheca Tichoniana" (or a close variant). That these items are not necessarily all from Tycho's library is manifest when we notice among them a copy of Kepler's *De stella nova*, published in 1606, five years after Tycho's death.

As it happens, the well-annotated 1566 *De revolutionibus* belongs to the small subset of books bearing both the 1642 Prague Jesuit College inscription and a variant of the "Ex Bibliotheca Tichoniana" inscription, but with no further supraexlibris identification. Hence either the early Jesuit librarian knew something we do not about the origin of the book, or else he made an intelligent guess. In any event, a detailed examination of the entire set of books reveals a wide variety of annotators, and comparatively few notes by Tycho himself. This means that the *De revolutionibus* might well have come via Tycho's library but with someone else's annotations, and further, that in the absence of an unambiguously identified sample of Tycho's hand, the Prague scholars faced a thorny problem in sorting out precisely which notes came from Tycho and which did not.

The two most interesting items in the Tychonic group are the *De revolutionibus* and a short manuscript entitled *Tychonis Brahe Triangulorum planorum et sphaericorum Praxis arithmetica*; the putative identification of this latter item has played a crucial role in the subsequent claims concerning the handwriting in the *De revolutionibus*.

The *Triangulorum praxis* manuscript is bound following a printed work, Rheticus' *Canon doctrinale triangulorum* (Leipzig, 1551), which bears on its title page the inscription "Collegii Caesarei Societatis Jesu Pragae 1642, Ex Bibliotheca Tichoniana, Bibliothecae Mathematicae."[96] In 1886, F.I. Studnička published a facsimile of the *Triangulorum praxis* under the assumption that it was an autograph manuscript of Brahe's.[97] In his 1890

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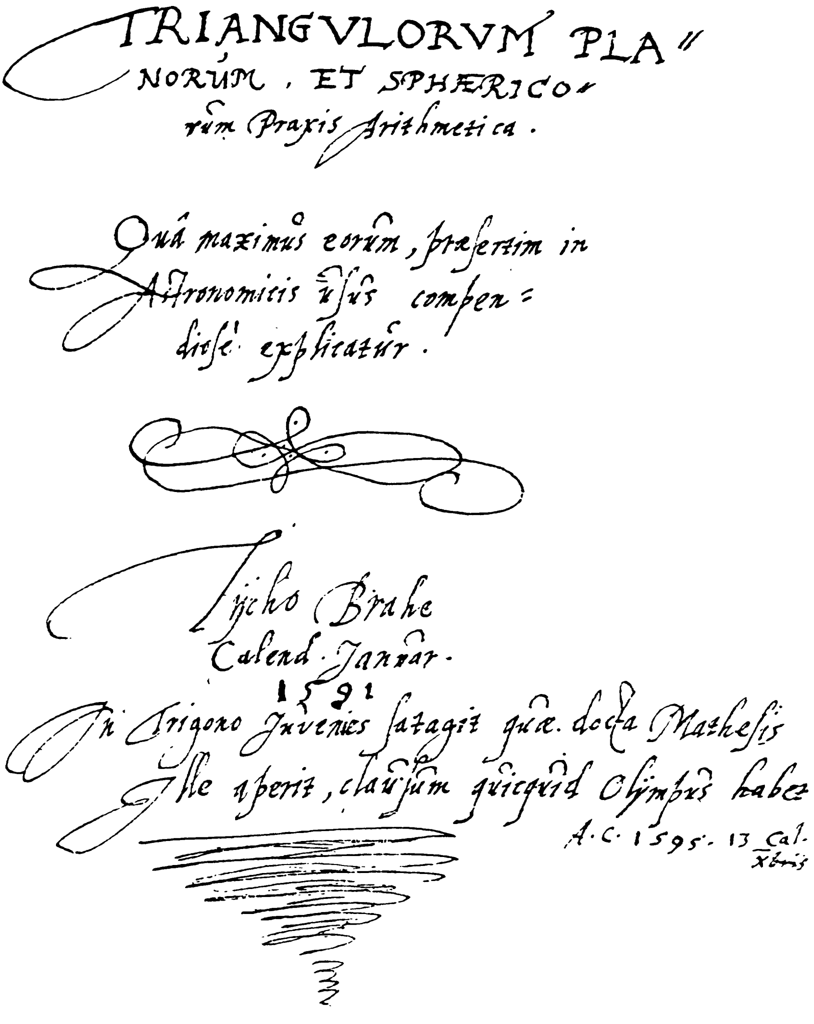
[95] Bartholomew Scultetus, *Cometae . . . 1577* (Görlitz, 1578), shelf mark M45 = 14 F 284, contains Tycho's notes, for example, on f. E2v, without any other identifying marks.

[96] Shelf mark M12 = TB12 = 14 C 20.

[97] F. I. Studnička (ed.), *Tychonis Brahe Triangulorum planorum et sphaericorum praxis arithmetica* (Prague, 1886; reprint Vaduz, 1984).



TRIANGVLORVM PLA-
NORUM, ET SPHERICO-
rum Praxis Arithmetica.

Qua maximus eorum, præsertim in
Astronomicis usus compen=
diose explicatur.

Tycho Brahe
Calend. Januar.
1591

In Trigono Juvenes satagit quæ docta Mathesis
Ille aperit, clausum quicquid Olympus habet

A. C. 1595. 13 Cal.
Xbris

Fig. 4. The title page of the trigonometric manuscript from Tycho's library, now at the University Library in Prague. In the last century, this manuscript was mistakenly believed to be in Brahe's hand and was used to argue that Tycho himself had annotated the Copernicus volume in the same collection.

biography of Tycho Brahe, J.L.E. Dreyer remarked that "Tycho has written his name under the title of the MS., but the handwriting of the remainder does not seem to be his"[98] (Fig. 4). Dreyer's footnote prompted Studnička to defend the attribution more vigorously in his *Prager Tychoniana* (1901), and there he specifically mentioned his opinion that the hand of the *Triangulorum praxis* strongly resembled the writing of the *De revolutionibus* marginalia. Dreyer, in the *Opera omnia Tychonis Brahe* volume 1 (1913), responded that while the manuscript clearly belonged among the Tychonic material (Tycho having mentioned it in a letter of 14 March 1592 to Hagecius), it was surely not in Tycho's hand.[99] He noted in particular that the very characteristic two-stroke "M" appearing in the *Triangulorum praxis* was *never* used by Tycho; by this time Dreyer also doubted the authenticity of the signature on the manuscript's title page, remarking that neither the "T," "B," nor "h" were typical of Brahe's autograph. However, Dreyer's comments, buried in the notes of the *Opera omnia*, were overlooked by a series of subsequent scholars, who continued to assign the *Triangulorum praxis* to Tycho's hand. As a result, in an unwittingly circular argument, this manuscript served as a principal basis for attributing the *De revolutionibus* marginalia to Tycho Brahe when the recent facsimile was published.

For all that, the notes in the Prague *De revolutionibus* and the *Triangulorum praxis* bear only a superficial resemblance to one another. Many letters, to be sure, including the two-stroke "M," are similar, but it seems out of the question that both could have been written by the same person. Furthermore, they are both clearly dissimilar to Tycho's undisputed writing, as seen in his observation books, in the heavily corrected working draft of his *Progymnasmata*, and on numerous dedicatory inscriptions.

From the foregoing discussion, it is clear why Studnička and later scholars drew erroneous conclusions. Of all the items in the "Tichoniana" collection, the *De revolutionibus* and the *Triangulorum praxis* contain the vast bulk of the manuscript material and are superficially similar. On the basis of the books from his library preserved in Prague, we must conclude that Tycho himself was a stinting annotator, and there is essentially no way from the Prague material alone to determine which are the sparse bona fide notes in his hand. Hence it was easy to overlook any discrepancies between these short, scattered phrases and the extensive marginal material in the 1566 *De revolutionibus.*

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[98] *Tycho Brahe* (Edinburgh, 1890), footnote on p. 362.

[99] *TBOO,* I, 315; Brahe to Hagecius, *TBOO,* VII, 325:16–21—see our translation infra p. 62.

II. Wittich's Copernican Annotations

Paul Wittich owned and annotated at least four copies of Copernicus' *De revolutionibus*. Two are first editions from 1543, and two are the page-by-page reprint of 1566, which also contained Rheticus' *Narratio prima*. How or where Wittich got his copies we do not know; after Wittich's death Tycho Brahe presumably managed to get three of them, but of how these were later dispersed we know rather little. Today the four copies are found in Liège, Wroclaw, Prague, and the Vatican Library.

Few of the annotations are absolutely identical from one copy to another, although many are similar. The Vatican copy contains the remarkable planetary diagrams that are reproduced in full as Appendix I here. The Liège copy contains examples of the mathematical prosthaphaeresis method not found in any of the other books. The Wroclaw copy apparently stayed behind when Tycho obtained the others, and there its annotations were faithfully copied out by Valentine von Sebisch (1578–1657), but afterward the book wandered to Bavaria and to London, and only recently returned to its home town.

Of the four copies, the one now in Liège was distinguished by having a previous annotator—an unidentified scholar who has copied out seminal annotations from the astronomer Erasmus Reinhold. This Wittenberg teacher was one of the most thorough and attentive annotators of Copernicus' work. Thus, we begin our specific survey of the marginalia in these volumes with a brief examination of Reinhold's annotations and their relation to the Liège copy.

IIA. Reinhold's Annotations and the Liège *De revolutionibus*

Erasmus Reinhold was the most influential astronomical pedagogue of his generation.[100] As professor of astronomy at Wittenberg from 1536 until his death in 1553, he wrote several works that became standard items in the libraries of sixteenth-century astronomers: a much-used commentary on Peurbach's *Theoricae novae planetarum* (1542), the *Prutenicae tabulae* (1551), and a volume based upon his lectures, *Hypotheses astronomicae*, which appeared without attribution to him under the name of his student and successor, Caspar Peucer. In view of Reinhold's preeminent role in the Melanchthon circle and his connections to Copernicus through his sometime-colleague, Georg Joachim Rheticus, it is not surprising that he had an early and close interest in *De revolutionibus*. His fastidiously annotated copy, now preserved in the Crawford Collection of the Royal Observatory in Edinburgh, was as important in spreading his influence as were his publications.[101] In this section, we shall briefly describe some of these annotations in order to show the main lines of the Reinholdian tradition that were disseminated through Wittich's activities.[102]

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[100] See Owen Gingerich, "Reinhold, Erasmus," in Charles C. Gillispie (ed.), *Dictionary of Scientific Biography*, XI (New York, 1975), pp. 365–67 and "The Role of Erasmus Reinhold and the Prutenic Tables in the Dissemination of the Copernican Theory," *Studia Copernicana*, 6 (1973), 43–62. For a criticism of some points in these articles see Edward Rosen, "Tycho Brahe and Erasmus Reinhold," *Archives Internationales d'Histoire des Science*, 32 (1982), pp. 3–8. See also Robert S. Westman, "The Melanchthon Circle, Rheticus, and the Wittenberg Interpretation of the Copernican Theory," *Isis*, 66 (1975), 165–93.

Reinhold's annotations are extensive and thorough: it is difficult to find an error in the text not already marked by him. Throughout, Reinhold proves remarkably aware of Copernicus' sources (such as Giorgio Valla, Johannes Werner, or Regiomontanus' *Epitome*), even when Copernicus does not credit them explicitly. Reinhold sums up his approach to Copernicus' opus by a motto inscribed on the title page, a paraphrase of the chapter title I,4: *Axioma Astronomicum. Motus coelestis aequalis est & circularis vel ex aequalibus & circularibus compositus.* ("The axiom of astronomy: Celestial motion is uniform and circular, or composed of uniform and circular motions.") There is nothing here about a revolutionary new cosmology, nothing about the earth orbiting like a planet about a stationary sun. Instead, Reinhold is fascinated by the use of pure circles to replace the Ptolemaic equant by an alternative mechanism. The marginalia throughout the volume verify this interpretation of Reinhold's interests. The cosmological chapter I,10 is virtually unglossed except for the correction of the periods of Venus and Mercury.

Book III, concerning the precession and the relative motion of the earth and sun, in contrast to the cosmological sections is generously annotated. Several long glosses discuss chronology. Others concern the observational basis for precession and the obliquity, where Reinhold regularly includes Werner, an antagonist whom Copernicus assiduously avoids mentioning. Chapter III,20 contains some of the most characteristic and widely copied of Reinhold's notes. The three different schemes for the solar theory are numbered in red, (f. 91) *I Per eccentri eccentrum*, (f. 91v) *II Per epicycli epicyclum*, and (f. 92) *III Per Eccentrepicyclum* (Fig. 5). In two paragraphs on f. 91v, Reinhold grapples with the technicalities and obscurities of the text; the longer of these paragraphs is found in five other copies of *De revolutionibus*,

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[101] Reinhold writes in a variety of patterns, but a very legible half Roman, half cursive style characterizes his hand both here and in other documents, including letters and his manuscript commentary on *De revolutionibus*. There is no evidence that any of the more variant forms of script in the book come from anyone other than Reinhold. Reinhold's *De revolutionibus* undoubtedly passed to his son Erasmus, who was also an astronomer, but its subsequent whereabouts until it was purchased by Lord Lindsay (later the Earl of Crawford) in the late 1800s is entirely unknown. The identity of the annotator and the significance of the notes seem to have passed entirely unnoticed until 1970 (see the 1973 article cited in n. 100).

[102] A transcription and translation of the most important notes will appear in *Census*, 1543 Edinburgh 1 (see n. 3).

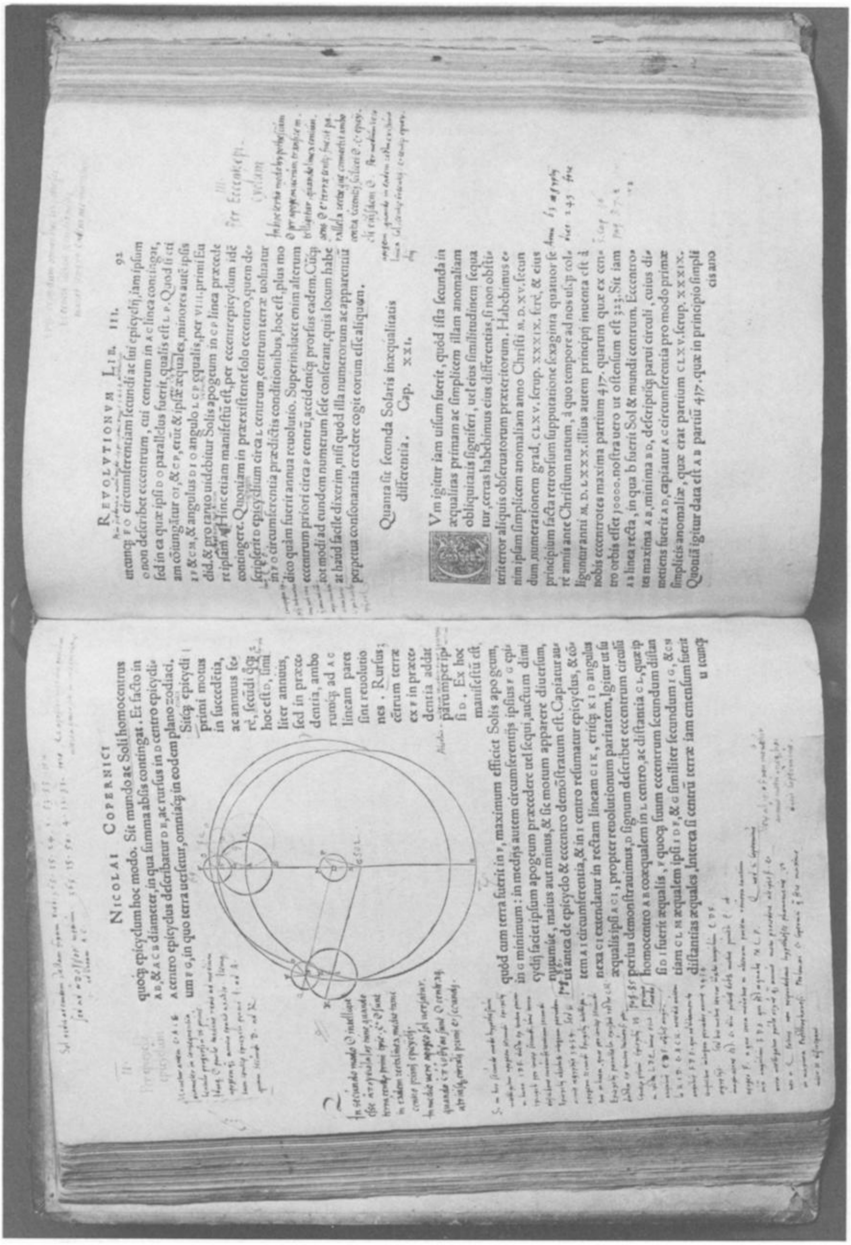

Fig. 5. Erasmus Reinhold's annotations on ff. 91v-92 of his copy of Copernicus' *De revolutionibus*. (Courtesy of the Astronomer Royal for Scotland, Crawford Collection, Royal Observatory, Edinburgh).

including two of those owned by Wittich. We shall return to this aspect of Reinhold's annotations at the end of this subsection.

Reinhold's copy retains its original blind roll-stamped binding, impressed with his initials *E R S* (Erasmus Reinhold of Saalfeld). In contrast, two copies containing major transcriptions of his annotations have lost all traces of their earliest provenances. One is at the University of Liège (a copy later owned and annotated by Wittich), and the other is at the Herzog August Bibliothek in Wolfenbüttel.[103] An unidentified early hand, typical of the Wittenberg scholars, has copied a major block of Reinhold's notes into the Liège copy, making a close imitation of the various sizes and patterns of the original annotations. The absence in Liège of certain of Reinhold's notes suggests that the transcription was produced while Reinhold was still actively glossing the book. In that case the copy may have been made by someone associated with Reinhold at Wittenberg, but even with such a clue it has so far proved impossible to identify the copyist.

The Wolfenbüttel *De revolutionibus* provides yet another copy of the Reinhold notes. Our detailed comparison among these three first editions, Edinburgh, Liège, and Wolfenbüttel, establishes that the Wolfenbüttel glosses were copied directly from Liège rather than from Edinburgh. The Wolfenbüttel copy thus allows us to deduce that the Liège volume existed in an independent state, with only the Reinhold annotations, before Wittich added his own second gloss. In other words, Wittich somehow purchased or inherited a copy with Reinhold's annotations already in place, rather than hiring a scribe to copy out Reinhold's annotations from the original.

How, then, did the young Wittich gain such access to the Wittenberg astronomical tradition? It is possible, but relatively unlikely, that he obtained the annotated *De revolutionibus* while an undergraduate at Leipzig, where he had enrolled in 1563. At that time the mathematics professor, Johannes Homelius, had just died; among the remaining astronomers was Bartholomew Scultetus, who had matriculated at Wittenberg in 1557 and who may well have studied astronomy under Caspar Peucer, Reinhold's successor there.[104] Scultetus certainly knew Wittich in later years and no doubt they became acquainted when Wittich was a student in Leipzig. Several copies of *De revolutionibus* annotated in Leipzig around this time survive, and their pattern of marginalia is quite different from that in Wittich's Liège copy.[105] Even Scultetus himself had difficulty in obtaining a copy, since he recorded the annotations from Homelius in a small notebook rather than in the margins of the book.[106]

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[103] The Liége copy is Res MS 69 C, *Census*, 1543 Liége; the Herzog August Bibliothek copy is 21.1 Astron fol, *Census*, 1543 Wolfenbüttel 1.

[104] For Scultetus' 1557 matriculation, see *Album Academiae Vitebergensis* (supra n. 25), p. 332; for a brief biography of Peucer see Robert Kolb, "Caspar Peucer's Library: Portrait of a Wittenberg Professor of the Mid-Sixteenth Century," *Sixteenth Century Bibliography*, 5 (St. Louis Center for Reformation Research, 1976).

[105] The following copies have notes derived from Homelius: *Census*, 1543 New Haven 1; 1543 Schweinfurt; 1543 Gotha 1.

Three years later, in Wittenberg, Wittich found a larger astronomical fraternity. Caspar Peucer had assumed Reinhold's position as the higher professor of mathematics. Surviving lecture notes inform us that mention of Copernicus was reasonably common but that cosmology was ignored in the elementary classes taught by Sebastian Theodoricus and Bartholomew Schönborn; the latter had presumably been a student of Reinhold's.[107] Although we know little about specific copies of *De revolutionibus* in circulation at Wittenberg in the late 1560s, there were likely some containing transcriptions of Reinhold's notes, perhaps even the very one that Wittich obtained.

If Wittich did not acquire his annotated copy in Wittenberg, there is the potential route through his family mentioned earlier: his uncle Balthasar Sartorius was an aquaintance of Rheticus', as was a Johannes Wittich, both of whom were members of the humanist circle in Wroclaw.[108] Either man could have provided an avenue for obtaining a *De revolutionibus* with a Wittenberg provenance.

In any event, Wittich managed to acquire a singularly interesting set of annotations in what is now the Liège copy. One of the most fascinating aspects of the Wittenberg tradition found in this copy comes with the material written on additional pages at the back of the book. Most of these pages have been transcribed directly from the additional leaves Reinhold appended to his copy, but in Liège there is some material no longer found in the Edinburgh volume. One page, with a complex diagram of planetary epicycles, is labeled "Primus modus," which refers back to the first of Reinhold's hypotheses listed in the marginalia on ff. 142–43 of his De revolutionibus (where the planets are discussed in V,4). The next page, following the same system, is labeled "Secundus modus." The nature of the copying suggests that these were originally part of Reinhold's papers. Copernicus did not explicitly describe a third mode for the planets (as he did for the solar theory), but we shall see that Wittich nevertheless continues such a scheme with a "third hypothesis" in his material at the back of the Vatican volume. It is to that copy that we next turn.

IIB. The Vatican Wittich Copy

Ottoboniana 1902, in the manuscript collection of the Biblioteca Apostolica Vaticana, is bound in red-orange morocco with the arms of Pope Pius IX (1846–78) gold-stamped on the spine. It has, therefore, lost much of the physical evidence of its earlier provenance, but part of its history can be deduced from the Vatican records. At some point around the time of the Thirty Years' War, the copy was brought to Sweden and subsequently it entered the collection of Queen Christina (1626–89). When Christina abdicated in 1654 and converted to Catholicism, a move that earned for her the epithet "Mad," she took the book to Rome, where it appeared in the 1655 catalogue of her library.[109] After Christina's death, her books were acquired in 1690 by Pope Alexander VIII (1610–91), the former Cardinal Pietro Vito Ottoboni.

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[106] Bamberg, Staatliche Bibliothek, shelf mark J H Msc astr 3; see Ernst Zinner, *Entstehung und Ausbreitung der Coppernicanischen Lehre* (Erlangen, 1943), p. 455.

[107] See Owen Gingerich, "From Copernicus to Kepler: Heliocentrism as Model and as Reality," *Proceedings of the American Philosophical Society*, 117 (1973), 513–22.

[108] See n. 22.

The text of Ottoboniana 1902 has been richly annotated throughout by Wittich, including four preliminary pages and 30 pages following f. 196. The first annotations derive from Erasmus Reinhold, undoubtedly via Wittich's Liège copy. They include the telltale motto on the title page about the axiom of astronomy. On ff. 54 and 163 is an observation of a conjunction of Venus and Regulus dated 16 September 1574, and on f. 57v one of a conjunction of Jupiter and Fomalhaut dated 8 November 1572; the observations are also in the Liège copy. On the introduction *Andreae Osiandrj* is added in red ink.

The manuscript leaves numbered ff. 197v-211v are primarily drawings of lunar or planetary circles and lead from a heliocentric to a semi-geoheliocentric system. These leaves are dated between 27 January 1578 and 17 February 1578. Another diagram of the same series, probably slightly earlier, is found on f. 135, and there are others on ff. 94-94v. These diagrams are reproduced and discussed more fully in Appendix I.

The first diagram is labeled *tertia hypotheseon* and refers to Wittich's extrapolation from the solar theory (where Reinhold has noted three modes in the margins of his *De revolutionibus*) to the planets; here Wittich uses the so-called "eccentreccentric" with a small eccentrically placed circlet on which the eccentric or deferent circle rides, a scheme that Copernicus introduced as the initial solar arrangement, but which he ignored with respect to the planets. In this and subsequent diagrams the orbis magnus of the earth is represented by a finely drawn double circle. The diagrams immediately following attempt the same procedure for the earth, the moon, Venus, and Mercury. A second series (ff. 201–203), begun a few days later, explores the so-called first mode or eccentrepicycle arrangement in which the epicyclet is on the planetary deferent; this strategy is completed with Mercury on f. 203. A group of three trial solar diagrams (f. 203v–204v), rich with parallelogram transformations, includes a particularly suggestive one with an extra, intermediate-sized circle that just might have been catalytic for the geocentric pathway a few days later. The next series, however, dated 1 Feb A[nno 15]78 completes the pattern for the second mode, Copernicus' "epicycle on an epicycle" on the deferent (ff. 205–207).

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[109] Vatican MS lat. 1871, pp. 88–91.

There now follow a series (f. 207v–210) in which *Terra* has replaced the sun as the center, with the comment (f. 208) *Haec nova hypotheseon ratio a me reperta A[nn]o 78 D 13 Feb* ("This new system of hypotheses occurred to me on 13 February 1578"). For each situation (the three superior planets, Venus, Mercury) the diagrams are given two different ways, with the epicyclet near the center of the orbit, or on the deferent and carrying the larger epicycle (which is clearly the solar orbit equivalent). The fact that the small epicycles for the earth, Venus and Mercury, each with an annual rotation, can be placed at the center in each case, now apparently allows Wittich to concatenate the entire arrangement into a partially unified scheme, which is shown in its simplicity (without the small merged circles) in f. 210v. We will discuss the further significance of this extraordinary diagram in Section III and in Appendix I.

IIC. The Prague and Wroclaw Wittich Copies

Like the Liège and Vatican first editions (Nuremberg, 1543), Wittich's Prague and Wroclaw second editions (Basel, 1566) include no trace of his ownership apart from the recognition of the handwriting itself. The Prague copy, however, retains its original blind-stamped pigskin binding with rollstamps dated 1550. Since the rollstamps remained in use long after they were made, their presence does not preclude Wittich himself from having had the book bound. It would be of interest to answer this question, because the volume includes 21 blank folios at the beginning and 71 at the end, and it might help clarify Wittich's intentions concerning the book if we could know whether it was his choice to include these worksheets. In any event, he never used them.

The earliest information on provenance contained in the book is the inscription alluded to earlier, *Ex Bibliotheca et Recognitione Tichoniana* in the hand of a Jesuit librarian in 1642. We have already described Tycho's extended campaign to buy Wittich's library, and we assume that this was one of three copies brought by Monaw to Tycho in October 1600, but the only one to have retained any connection with the Danish astronomer.

As we shall indicate more extensively in the next subsection, it is, with several important exceptions, difficult to establish precisely when the various annotations were made. However, on f. 93 the year 1580 is used in an example for calculating the solar apogee. The volume is annotated throughout, including Book VI and Rheticus' *Narratio prima* at the end, which often escape annotators who work over Books IV and V fairly thoroughly. The only extensive section without any notes is the star catalogue (ff. 46v–62v); except for the 1572 and 1574 observations mentioned earlier in the Liège and Vatican copies, Wittich seldom marks this list of the thousand Ptolemaic stars.

The early portions of Book I are particularly systematically annotated, with numbered paragraphs in chapters 5 and 6. On the page with the heliocentric diagram (f. 9v) is an interesting panegyric (also found in Liège) beginning:

There in the middle sits Phoebus
With his shining golden hair,
As if king and emperor of the world,
Holding sceptre and helm
In whom all celestial virtues reside.

The marginalia include not only cross references to other folios in *De revolutionibus,* but also citations to other authors or works such as Regiomontanus' triangles, his *Epitome of the Almagest,* Johannes Stadius, Petrus Nonius, Ramus, Cardano, Censorinus, Reinhold, and John Dee. The latter reference (on f. 124v) is particularly significant because it concerns parallax distance measurements, a topic of considerable interest not only to Wittich but also to his contemporaries, who realized that distance measurements to the nova of 1572 and the comet of 1577 held important clues to the nature of the universe. The citation, unique in the Prague copy, to "Johannes Lee[110] in libello parallatico suo" refers to Dee's *Parallaticae commentationis praxeosque nucleus quidam* (London, 1573), a book on the 1572 nova whose title specifically emphasizes the question of its distance.

One of the most striking features of the Prague annotations is the uniformity and neatness of the hand, and there are places such as ff. 22v, 26, 65, etc. where small pieces of paper are pasted over earlier notes to make the book tidier.[111] It almost appears as if the text was being prepared for possible publication or presentation, but its incompleteness in spots suggests that any such project was abandoned. For example, on f. 94, Wittich has inscribed a large, carefully drafted diagram of four circles, very similar to the ones on this page in Liège and Vatican, and resembling the models in the back of the Vatican copy. However, in Prague there is no supporting text.

Folio 97v, at the end of Book III, contains a large space, surely a temptation for any annotator, and Wittich has filled it in three of his four copies, each time with technical notes relating to Copernicus' discussion of the equation of time (the difference between the meridian passages of the true and mean sun). Copernicus made a numerical error in comparing the value of the equation of time in antiquity with his own time, something Wittich overlooks in Liège and Vatican. In Prague Wittich noticed the "egregious discrepancy" and probably then cancelled his long note in Vatican (but not the similar one in Liège); although his own calculation comes closer than Copernicus', he still misses because of an incorrect right ascension at the time of the Olympiad. The differences are:

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[110] Horský (supra n. 7), points out that it is possible to read the elaborate D on Dee's title page as an L.

[111] But Wittich adds new paper in his other copies as well, for example, Vatican f. 132.

Prague	2°	24′
Correct[112]	2	13
Copernicus	1	53

Clearly, in this case at least, the Prague annotations supersede the Liège and Vatican notes.

Unlike the Prague, Liège, and Vatican copies, Wittich's second edition, now in the Wroclaw University Library, carries a fuller story of its wanderings through several intermediate locations. Since Tycho in his quest for Wittich's library mentioned only three copies of *De revolutionibus*, we can conjecture that he ultimately received only three and that this one was left behind in Wroclaw. At some time around 1604 its annotations were carefully copied by Sebisch of Wroclaw, so we may safely assume that the Wittich book remained in the area of his home town for some years after his death. A faint inscription, barely legible under ultraviolet, seems to read *Ex Bibliotheca Collegii Pollingeri*, which may refer to Polling in Bavaria; it is likely that the *Narratio prima* was removed as part of the Roman censorship during this period. A considerably defaced inscription gives the book a private Munich location in 1816, and subsequently there is a duplicate stamp from the Royal Library in Munich. The book was acquired by the Royal Astronomical Society in London, who rebound it, but since the Society considered it an imperfect duplicate, they sold it in 1949. The book was eventually acquired by the late Colonel Roman Umiastowski, an expatriate Polish collector and book dealer in London. Because the book was imperfect, Umiastowski cut it up to repair other copies of *De revolutionibus*, but fortunately we discovered this state of affairs before any of the repaired copies were sold. Umiastowski tried with partial success to reassemble the book before he donated it to his alma mater, the University of Wroclaw, and subsequent exchanges of pages have completed it—all too well, including the *Narratio prima* pages added by Umiastowski from another, unrelated copy of this edition.

The annotations in the Wroclaw copy are rather closely related to those in Prague, such that in the first eleven chapters most of the Prague annotations are summarized and condensed into the Wroclaw book.[113] Occasionally new and different material is included. For example, in the trigonometrical section Copernicus forgot the ambiguity in the case where an angle, an adjacent side, and an opposite side are given. Wittich comments on this in Prague, but in Wroclaw he adds that P. Nonius has criticized Copernicus for this oversight.[114] The annotations are comparatively less frequent in Book II although occasionally there is a long comment with no counterpart in Prague. The marginalia pick up again in Book III, with many ancillary tables and diagrams similar to those in Prague. Despite the similarities there are also conspicuous differences, such as on f. 91v in Book III,20 where Wittich transfers from the Liège copy a long passage from Reinhold (absent in Prague and Vatican).

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[112] For an analysis and recomputation of Copernicus' error, see N. Swerdlow and O. Neugebauer, *Mathematical Astronomy in Copernicus's De Revolutionibus* (New York, 1984), p. 178.

[113] Some of the Wittich Wroclaw pages have been washed, making the notes difficult to decipher, but Sebisch's copy provides a convenient aid.

[114] See Petrus Nonius, *Opera . . . regulae et instrumenta artis navigandi* (Basel, 1566), pp. 179–81 and *De arte ratione navigandi* (Coimbra, 1573), pp 66–67.

Wittich's interest in the lunar theory of Book IV may have been a later development. That book is particularly well glossed in Wroclaw and Prague compared with Liège and Vatican. On two successive folios (108 and 109) sections of the margin have been torn out of the Wroclaw copy and replaced with fresh paper. On the new paper on f. 108v Wittich writes that the maximum prosthaphaeresis of the moon is 5° 4′, but this passage is crossed off and adjacent to it the value of 5° 0′ appears. In Prague Wittich begins with 5° but writes over it to give 4° 54′ 10″. (A solitary note in Vatican says that according to Copernicus the figure is 5° 9′ 44″. . . .) Elsewhere on this folio Wroclaw has an angle 119° 9′ 12″, but in Prague the 12 is overwritten 6 *NB NB*, suggesting that in this instance Prague superseded Wroclaw. As we shall notice in the next subsection, Wittich was especially interested in the distances to the moon and planets, so it is not surprising to find the relevant chapters (IV,17–20) heavily annotated in both Wroclaw and Prague.

The remaining lunar chapters in Wroclaw, as well as Books V and VI, are only sparsely marked, in conspicuous contrast to Prague. There are, however, three interesting exceptions. At the bottom of f. 162v Reinhold and a few other annotators have added what is apparently a piece of missing text, part of a privately circulated errata list to *De revolutionibus*.[115] Liège includes these lines, and Wittich carefully copied them into his three other copies. Secondly, f. 188 is heavily annotated compared to all the other pages around it, and it turns out to be a page from Liège (a first edition) that has been interchanged with Wroclaw (a second edition). Finally and quite surprising, on the blank expanse on f. 139, Wittich has copied from the back of the Liège volume the large bi-epicyclic diagram and the exact accompanying text, or at least the first part of it. This material appears in splendid isolation, and Wittich's intentions here are inscrutable; nevertheless, his diagram reaffirms his general use of *De revolutionibus* as a corpus of geometrical constructions rather than as a resource for table making.

IID. Why annotate four copies of *De revolutionibus*?

Why did Wittich carry about with him multiple annotated volumes of *De revolutionibus*? How were they meant to be used?

In the absence of firm evidence, we must fall back upon analogy with other similar cases as well as clues extracted from a careful comparison of the placement, grammar, and content of the annotations. Proceeding in this manner, we conclude that the volumes served a combination of private and public purposes. First, the books were, of course, Wittich's own instruments of private study. Into Liège, Vatican, and Prague, Wittich transferred numerous Reinholdian paraphrases of Copernicus' arguments and marginal excavations of Copernicus' bibliographical sources. He made, and remade, numerous calculations to confirm or extend the text itself. Secondly, Wittich used the books as instructional tools, and we have surviving examples where his occasional students or colleagues copied out key annotations. Finally, Wittich might have annotated at least one copy (Prague) with the intention of printing an edition of *De revolutionibus* with commentary.

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[115] See Owen Gingerich, "An Early Tradition of an Extended Errata List for Copernicus's *De Revolutionibus*," *Journal for the History of Astronomy*, 12 (1981), 47–52.

In fact, Wittich is by no means unique as an astronomer who annotated multiple copies of his books. Wittich's contemporaries, Johannes Praetorius and Michael Maestlin, each annotated at least two copies of *De revolutionibus*.[116] His sometime student Duncan Liddel carried two copies of the book back to Aberdeen. In the next generation Johannes Broscius annotated two of his own copies as well as a third belonging to the Collegium Maius in Cracow. And two annotated copies of the Regiomontanus *Epitome* survive with Erasmus Reinhold's annotations.[117] With one exception, we can only speculate as to why these scholars wrote in second copies of the same work; that exception is Michael Maestlin, for which a letter survives informing us that he obtained the second copy in order to prepare it for a new edition.[118]

Evidences of Wittich's private use abound in the marginalia of these volumes; we shall now examine in detail a representative example.

Folio 8 comes near the beginning of Book I,10, the cosmological chapter, where Copernicus discusses the distances between the earth and sun, and the spacing of the inner planets. All four of Wittich's copies are heavily annotated here. In contrast, Reinhold's copy has only a single note, *Idem est in historia Caroli magni*, alongside Copernicus' remark that Averroes had reported a transit of Mercury.[119] Reinhold's note is the *only* annotation on this page that is completely identical between any two of Wittich's copies, and it appears in all four. However, we find some parallel passages, of which the following texts (in Liège and Vatican) are given primarily to show the nature of the differences in the most similar annotations.

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[116] Praetorius copies: *Census*, 1543 New Haven 1, 1543 Schweinfurt; Maestlin copies: *Census*, 1543 Schaffhausen, 1543 Stuttgart 1; Liddel copies: *Census*, 1543 Aberdeen 2, 1566 Aberdeen 2; Brocius copies: *Census*, 1543 Cracow 1, 1566 Cracow 4.

[117] Wroclaw University Library, shelf mark 552608, and Paris Observatory Library, shelf mark 1196.

[118] Maestlin to Kepler, 25 July 1613, *Johannes Kepler Gesammelte Werke*, vol. 17, pp. 53–54; we thank Alain Segonds for this reference.

[119] The alleged Mercury transit was reported in a chronicle of the life of Charlemagne, but how Reinhold had access to it is still unresolved; for a discussion of sources on the transit see Bernard Goldstein, "Some Medieval Reports of Venus and Mercury Transits," *Centaurus*, 14 (1969), 49–59.

(Neither the Prague nor Wroclaw copies have anything comparable at this point.)

L: Qualium enim semidiameter Orbis Magni ponitur 1152 semid: Terrae.
V: Qualium enim semidiameter Orbis Magni ponitur 1152 S. T.,

L: Talium ex Maxima digressione ♀ reperta semidiameter
V: Talium ex maxima digressione ♀ à ☉ reperta est semidiameter

L: Orbis ♀ qui est epicyclus Alphonsinis 828 3/4
V: o[r]bis ♀ (qui semidiameter est Epicyclus ex Veterib[us] 828 3/4

L: Totaque diameter 1657 1/2. Mercurii
V: Totaque diameter 1657 1/2. Ex quib[us] et[iam] constat Orbis ☿

L: Vero semid: Deferentis reperta earundem 231 7/12.
V:

L: Totaque Dimetiens 463 1/6 Secundum Copernici
V: diameter 463 1/6

L: demonstrationes. Unde prodit adgregatum
V: Ut sit

L: utriusque Diametri deferentis ♀ & ☿
V: utriusque Epicyclorum ♀ & ☿ adgregatum diametrorum

L: 2120 2/3 Quod contineri Alias inter Concavum Orbis ☉ &
V: 2120. Comprehensum Vulgo inter Concavum Orbis ☉ &

L: Convexum ☾ deberet. Cum tamen illud constet solum[mod]o
V: Convexum Sphaerae ☾ae Cum tamen illud

L: esse 1033 1/4.
V: 1033 S.T. tantum esse, demonstratione pateat.

On f. 8 Copernicus first mentions the problem of an absolute distance to the sun, which the ancients derived in two ways, one by stacking the spheres in a nested, plenum fashion, as in Ptolemy's *Planetary Hypotheses*, and the other by the Hipparchan lunar eclipse method as modified by Ptolemy in *Almagest* V,15, which relates the solar and lunar distances by means of the apparent diameters of the sun, moon, and the earth's shadow. Copernicus gives the challengingly discrepant values of 1151½ and 1160 earth radii for the two methods. His own mean value of 1142 (from the eclipse method) is not given until Book IV, in a section cited by Wittich in both the Prague and Wroclaw copies. Wittich gives no fewer than nine values for the earth-sun distance, including the three Copernican numbers for minimum, mean, and maximum distance. In general the sources of his distances are not specifically attributed and do not derive directly from the text on f. 8.

Near the bottom of this page Copernicus comments on the large size of the sphere of Venus according to Ptolemy (cited as an improbability in Osiander's introduction to the book). Venus' epicycle has a size of 447 relative to 600 in the *Almagest*, a scaled stacking size of about 910 earth radii (cited here by Copernicus), and a relative heliocentric size of 0.7193 astronomical units (cited by Copernicus on f. 161v). Wittich uses all these figures, including Copernicus' relative size scaled into several absolute dimensions depending on which value of the earth-sun distance he is using.

As an example of the stratagems Wittich explores, we can examine the curious passage transcribed above. There he calculates the sizes of the spheres of Mercury and Venus using Copernican numbers from later in *De revolutionibus* but compared to an earth-sun distance of 1152 earth radii. This number is similar to, but not exactly the same as, Copernicus' mean distance of 1142. However, instead of arranging these heliocentrically scaled spheres like nested Chinese boxes, Wittich sums them just as the epicycles would have been added together in the old Ptolemaic stacking scheme. This addition leads to 2120, which hardly compares meaningfully to 1033, "the distance between the concave orb of the sun and the convex sphere of the moon," (as Copernicus stated it). If any cosmological arrangement is implied by this wording, it must be geocentric, but with a strange admixture of heliocentrically scaled components. However, these numerical maneuvers, provoked by Copernicus' statement that Venus has sufficient space, anticipate Wittich's model building. The number 1033, as Wittich shows in the Liège copy, derives from the following calculation:

Minimum distance of sun	1103
Maximum distance of moon	69 3/4
Difference	1033 1/4

The source of these not-quite-Copernican (nor Reinholdian) numbers is found on f. 120 of Liège, where Wittich attributes this lunar distance to JoFrancus Offusius (fl. 1557). Offusius' little known *De divina astrorum facultate* (Paris, 1570) was the only book between the writings of Copernicus and of Kepler to discuss planetary distances in a systematic fashion.[120] The Vatican copy cites "Jofrantius" on f. 8, but none of his numbers, and in fact, it has the corresponding Copernican values of 1105;20 and 68;20 immediately above this citation.

Liège and Vatican each give, near the top of the page, yet other (unattributed) values for the earth-sun distance, 1121;20 and 1112 2/3 respectively. The Vatican number is from Offusius; the Liège number is very close to the value given in the Islamic Middle Ages by al-Farghānī,[121] a figure that had some currency in this period, but Wittich has criss-crossed off the large schematic table that contains this entry. In the Prague copy nearly the same table appears at the top of f. 8, but it has not been cancelled. Near the bottom a note explicates Copernicus' statement that there is plenty of room for Venus, a gloss entirely different from those in Liège and Vatican.

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[120] In his "On the Divine Power of the Stars Against a Decadent Astrology," Offusius attempted to derive the planetary distances from a calculation based on the Platonic solids, employing a numerical scheme reminiscent of Kepler's later geometrical usage of these same polyhedra. It is interesting to note that Tycho Brahe cites these numbers approvingly in his *Progymnasmata*, *TBOO*, II, 421:35.

[121] For tables of al-Farghānī's as well as Ptolemy's distances, see Albert Van Helden, *Measuring the Universe: Cosmic Dimensions from Aristarchus to Halley* (Chicago, 1985), p. 30, etc.; al-Farghānī's planetary distances would presumably have been available to Wittich through Alfraganus, *Rudimenta astronomica* (Nuremberg, 1537).

The annotations in the Wroclaw copy, while addressing the same kind of interests, use purely Copernican numbers from the later chapters of *De revolutionibus*. In a sense, Wroclaw is the most advanced and sophisticated of the copies, and it is tempting to guess that it was generally annotated last, especially because of its obviously unfinished state. The order of the other three presents a thornier problem, and since the books may well have been annotated more or less simultaneously, it is probably impossible to sort out their sequence and purposes. In some ways Prague is the neatest of the copies, but if it was being prepared for publication (rather than just containing personal study notes), then the project must have been abandoned, for it contains a table deemed obsolete in the Liège copy.

What might have started out as private use could also have been helpful to a student of *De revolutionibus*. A solitary reader could have studied the marginal glosses to facilitate understanding of the text. A reader of the Vatican copy, already quite familiar with Ptolemy's *Almagest*, would have found Wittich's diagrams at the back quite helpful, but would have found the Prague glossation (at least of Book I) less messy, more systematic and easier to follow. More likely, Wittich might have assisted actively in a kind of tutorial context. Wittich had a direct association with Duncan Liddel and John Craig, both of whom transcribed into their own copies annotations from one or more of Wittich's volumes.[122] There exists in Wroclaw an anonymous set of annotations that combines two traditions, the first deriving from Maestlin's Schaffhausen copy and the second from Wittich's Liège copy.[123] Internal evidence suggests that some of the annotations were made in Cassel, and hence probably while Wittich was there (although the possibility of a quite different transfer through the intermediary of John Craig's *De revolutionibus* cannot be excluded). Yet another copy of Wittich's annotations survives,[124] copied by Valentine von Sebisch, who was educated at Leipzig between 1593 and 1597 and, like Wittich, a native of Wroclaw. However, Sebisch's near-faithful copy was obviously made well after Wittich's death.

Several sixteenth-century astronomers had planned to publish commentaries on *De revolutionibus* or have left behind copious materials that might have been so intended.[125] The fact that Wittich neither published nor announced in any known surviving materials that he planned to publish such a commentary does not entirely exclude such an intention. The neatness of the Prague copying, careful consolidation and systematic numbering of many of the marginal paraphrases, and the regular use of lines to designate the specific placement of a comment suggest purposes more ambitious than private use. Furthermore, since the Prague copy has 21 blank folios bound into the front and 71 more following the printed text, it is tempting to imagine that Wittich intended to prepare a definitive version with an extensive apparatus of diagrams at the back and his own introduction at the beginning. These observations recall Horský's earlier suggestion that the marginal commentary "was probably intended for use in a later edition of *De revolutionibus*."[126]

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[122] Craig copy: *Census*, 1566 Edinburgh 3; for Liddel see n. 116.

[123] *Census*, 1566 Wroclaw 5.

[124] *Census*, 1566 Wroclaw 1 = Wroclaw University Library, shelf mark 363152.

Unfortunately, we have found no single explanation that persuasively accounts for the purposes or relationship among the several Wittich copies, nor any chronology for their possible use that we would regard as definitive. Nevertheless, whatever explanation may eventually tie together these unusual texts, we see that the Reinholdian tradition of marginal glossing continued even into the generation following Wittich's death.

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[125] Reinhold's unpublished commentary has been described by L. Birkenmajer, *Mikolaj Kopernik* (Cracow, 1900), pp. 622–29 and by A. Birkenmajer, "Le commentaire inédit d'Erasme Reinhold sur le 'De revolutionibus' de Nicolas Copernic," *La science au seizième siècle, Colloque International de Royaument 1–4 juillet 1957* (Paris, 1960), pp. 169–178, and was the subject of a doctoral dissertation by Janice Henderson, Yale University, 1973; Maestlin's list of intended publications, showing a commentary on Copernicus, is found in MS 15.3 Aug 2°, ff. 1–2 and 18–19 at the Herzog August Bibliothek, Wolfenbüttel; see also n. 118.

[126] See Z. Horský, notes to the "Brahe" facsimile of *De revolutionibus*, p. 14 (supra n. 7).

III. Reconstructing the Universe

Copernicus's sun-centered cosmos revealed a new connection between a planet's period of revolution and its distance from the sun. In the heliocentric system Mercury, the swiftest planet, naturally fell into place closest to the sun and Saturn, the slowest, moved at the outer boundary of the planetary system (with the other planets lying appropriately in between). "In no other arrangement do we find such a harmonious connection between the motion and the size of the orbits," exclaimed Copernicus in the climactic cosmological chapter of his *De revolutionibus*. The arrangement eliminated ad hoc explanations and provided a natural, systemic explanation for the rhythms and sizes of the retrograde motions, especially of Mars, Jupiter, and Saturn. For some, these revelations were compelling; for others they were worthy of praise but not commitment.[127] Copernicus' original disciple, Georg Joachim Rheticus, stressed the interconnections even more forcefully than did his master: "For all these phenomena appear to be linked most nobly together, as by a golden chain," he wrote in his *Narratio prima*, "and each of the planets, by its position and order and every inequality of its motion, bears witness that the earth moves."[128]

Another early commentator, Gemma Frisius (1508–55), expressed the contrast between Ptolemy and Copernicus in the idiom of Aristotelian demonstrative logic:

> While at first glance the Ptolemaic hypotheses may seem more plausible than Copernicus', nevertheless the former are based on not a few absurdities, not only because the stars are understood to be moved non-uniformly in their circles, but also because they do not have explanations for the phenomena as clear as those of Copernicus. For example, Ptolemy assumes that the three superior planets in opposition—placed diametrically opposite the sun—are always in the perigees of their epicycles, that is, a "fact-in-itself" [*το ὅτι*]. In contrast, the Copernican

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[127] Concerning the ongoing controversy over the role of aesthetics in Copernicus' motivation and argumentation, see Thomas Kuhn, *The Copernican Revolution* (Cambridge, 1957), pp. 171–81; Owen Gingerich "Crisis" versus Aesthetic in the Copernican Revolution," in A. Beer and K. Strand (eds.), *Vistas in Astronomy*, 17 (1975), 77–88; Imre Lakatos and Elie Zahar, "Why Did Copernicus" Research Program Supersede Ptolemy's?" in Westman (ed.), *The Copernican Achievement* (supra n. 2), pp. 354–83 and S. Toulmin's reply, pp. 384–92; Robert S. Westman, "La préface de Copernic au pape: esthetique humaniste et réforme de l'église," *History and Technology*, 4 (1987), 359–78 and "Proof, Poetics, and Patronage: Copernicus's Preface to *De revolutionibus*," in David C. Lindberg and Robert S. Westman (eds.), *Reappraisals of the Scientific Revolution* (Cambridge, 1989).

[128] G. J. Rheticus, translated by Edward Rosen, *Three Copernican Treatises* (New York, 1939, 1959, 1971), p. 165.

hypotheses necessarily infer the same thing, but they demonstrate a "reasoned fact" [δι ὅτι]. They are not based on anything incongruous with natural motions, from which a greater knowledge of the planetary distances is here deduced than from the former hypotheses. But if anyone wishes, he will be able to ascribe to the heavens those motions of the earth that he is considering (except for the first two) and thus use the same canons for calculation.[129]

Copernicus' beautiful linkages were of limited appeal. Most of those familiar with his work found a major difficulty in the conflict between the earth's alleged mobility and Aristotelian simple motion. In looking back on this period, an earlier historiography has tended to suggest that a compromise system was inevitable. By fixing the earth the ancient physics could be saved; by placing the planets in secondary orbits around the moving sun the Copernican linkages could be, in part, preserved. Best of all, Tycho's geoheliocentric scheme kept intact the systemic cause of the retrograde motion for the superior planets. As soon as someone recognized how to make the transformation, the Tychonic system seemed natural. Thus we find that Thomas Kuhn characterized Tycho's system as a "compromise solution;" Marie Boas and Rupert Hall spoke of it as "filling a need" between the old and the new planetary orderings; Tycho's editor and biographer J.L.E. Dreyer called it a "stepping stone" and went on to claim that "the idea of the Tychonic system was so obvious a corollary to the Copernican system that it almost of necessity must have occurred independently to several people . . ."[130]

This historiographical tradition makes the story too inevitable. The creation of Tycho's geoheliocentric system, as we view it, was filled with contingencies and conflict. As Alexandre Koyré remarked in 1948, "The history of scientific thought is not logical. The fact that Tycho Brahe came after Copernicus shows that history is not logical because, rationally, he should have appeared before him."[131] Koyré correctly noticed that this development was neither historically nor logically sequential. But having recognized this much, Koyré did not then identify the geometrical, physical, and observational constraints or the particular contexts of social relations within which Tycho actually constructed a new representation of the cosmos. In what follows, we want to focus on four problems: (1) appreciation of the domain of geometric possibilities, in particular, how to make transformations of planetary models from heliocentric to geoheliocentric systems; (2) assessment of the ontology of the spheres: What kind of reality did the spheres possess? Were they penetrable or impenetrable?; (3) Tycho's reports of his alleged attempts to observe a parallax of Mars; and (4) negotiation of the social credit associated with the discovery of a new world system. These four considerations were, in practice, mutually interwoven. We shall now see how this happened and how, as a result, it affects the history of this episode.

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[129] Reiner Gemma Frisius, in Johannes Stadius, *Ephemerides novae et auctae* (Cologne, 1560), sig. b3–b3v: "Quamvis vero hypotheses Ptolemaei prima facie sint plausibiliores, quam Copernici, non pauca tamen illae absurda committunt, dum stellae in suis circulis inaequaliter moveri intelliguntur, tum non habent tam evidentes τον φαινομένωμ causas, atque illae Copernici. Nam quod tres superiores planetae (ut demus exemplum) ἀκρόνυχοι, sive e diametro Solis positi, semper sint in perigeo sui epicycli, assumit Ptolemaeus, atque hoc est το ὅτι. Verum Copernici hypotheses idem illud necessario inferunt, ac demonstrant δι ὅτι. Neque quicquam fere absurdum naturalibus motibus committunt, unde hic amplior cognitio de planetarum distantiis colligitur, quam ex illis. Quin si quoque quispiam velit, poterit illos motus terrae, quos praeter duos primos ponit, ad coelum referre, ac uti iisdem Canonibus calculorum." The technical vocabulary of logic in this passage derives from *Posterior Analytics* 1.13 where Aristotle distinguishes syllogisms that demonstrate *that* something is true το ὅτι from those that demonstrate *why* something is true διότι.

[130] Kuhn, *Copernican Revolution* (supra n. 127), p. 202; Boas and Hall, "Tycho's World System" (supra n. 3), p. 256; J.L.E. Dreyer, *A History of the Planetary Systems from Thales to Kepler* (Cambridge, 1906; reprint, New York, 1953), p. 369.

[131] A. Koyré, "Les étapes de la cosmologie scientifique," *Revue de Synthèse*, 70 (1948), 30; reprinted in R. Taton (ed.), *Etudes d'histoire de la pensée scientifique* (Paris, 1966, 1973, 1985).

Before proceeding further, we must briefly consider a problem that lay beneath the controversy: the intersection of the orbs of Mars and the sun. As seen in Figure 6a, in the Copernican system the ratio of the size of the earth's orbit to that of Mars is 2:3. This is already established in Ptolemy's model, where the ratio of Mars' epicycle to its deferent is 2:3. The relative sizes of these circles must be preserved in the geoheliocentric transformation (Fig. 6b), and therefore Mars' orb necessarily slices through the sun's orb. As we shall notice, this essential point was initially missed by Nicholas Reymers Ursus, and perhaps by Paul Wittich as well. But Tycho Brahe regarded it as a genuine problem that had to be overcome before a geoheliocentric arrangement could be raised to the status of a world system. From a long perspective, one might regard this as a phase in the on-going critique of the relation between the geometrical devices and the physical nature of the spheres, a critique that had begun in the Latin West with Peurbach and Regiomontanus and consummated with Kepler.[132]

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[132] Concerning Peurbach and Regiomontanus and the continuation through Copernicus and Reinhold, see E.J. Aiton, "Peurbach's *Theoricae novae planetarum*: a translation with commentary," *Osiris*, 3 (1987), 5–43; Olaf Pederson, "The Decline and Fall of the Theorica Planetarum," Polska Akademia Nauk, *Studia Copernicana*, 16 = *Science and History, Studies in Honor of Edward Rosen* (Wroclaw, 1978), 157–85; Michael H. Shank, "The *Disputationes* of Regiomontanus: Medieval Astronomy in Renaissance Garb," read at the Philadelphia meeting of the History of Science Society, October 1982, and a related abstract, "Regiomontanus and Homocentric Astronomy," *Bulletin of the American Astronomical Society*, 14 (1982), 897; see also Janice Henderson's doctoral dissertation on Reinhold's Commentary (supra n. 125).

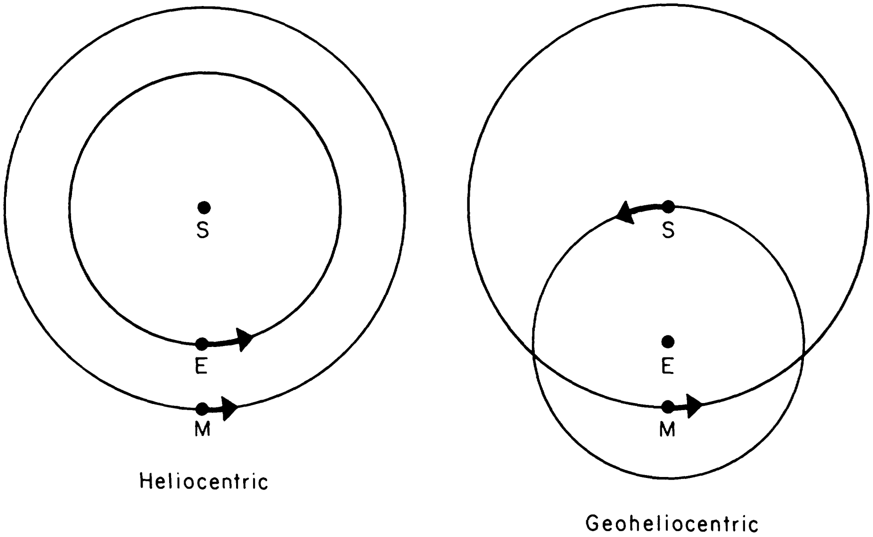

Fig. 6. a: Mars at opposition in the Copernican (left) and b: Tychonic system (right). The orbit of Mars must necessarily cut the orbit of the sun in Tycho's geoheliocentric arrangement, but the bodies themselves never collide because the sun is always at the center of Mars' orbit. Note that at opposition Mars is closer to the earth than is the sun, and all corresponding distances are the same in both systems.

IIIA. Tycho's Early Transformations and Wittich's Visit

In 1574 Tycho delivered an oration on the mathematical disciplines to the faculty and students at the University of Copenhagen. In passing, he mentioned that he was going to take the models and values of Copernicus and reduce everything to a system in which the earth was at rest. Tycho would have encountered precisely that program already as a student at the University of Wittenberg in the middle 1560s. Unfortunately, the text of the Copenhagen lectures contains absolutely nothing to show how

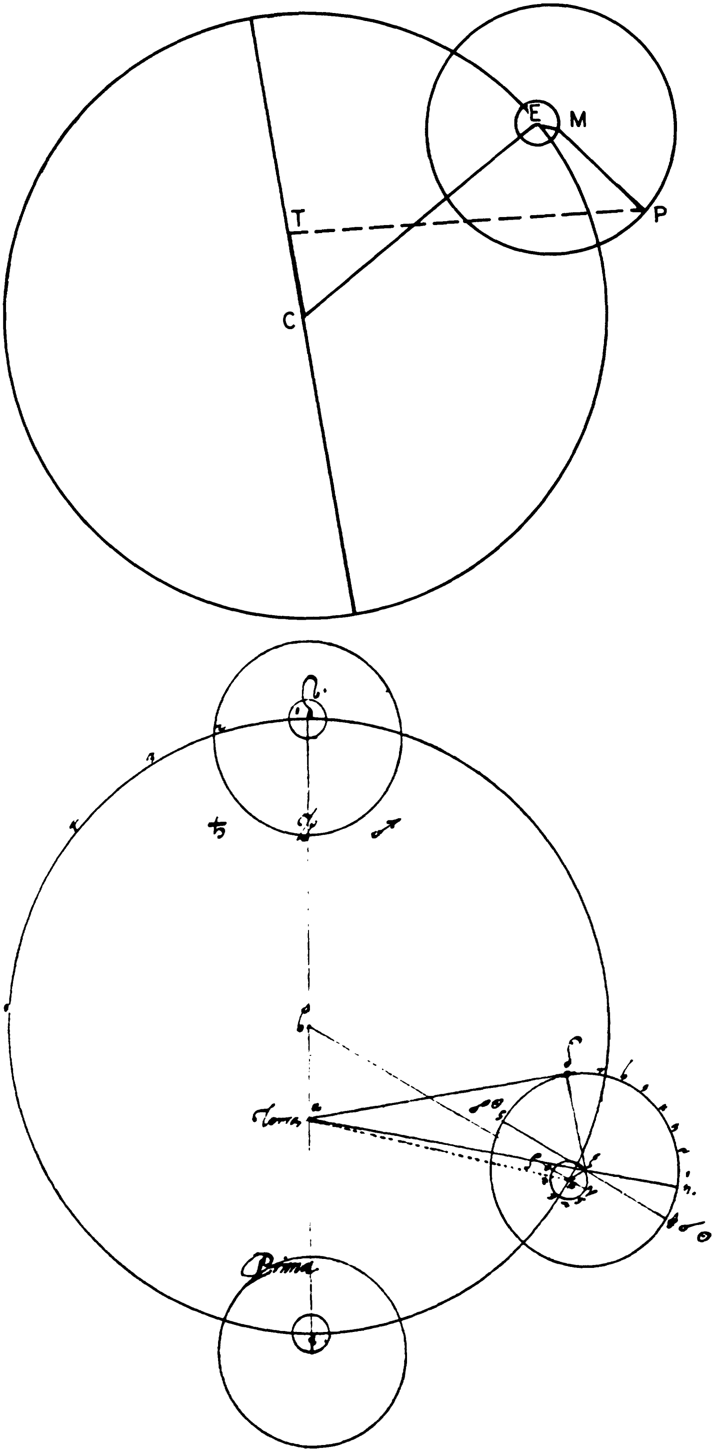

Fig. 7. "Tycho's hybrid theory for the superior planets," as hypothesized by Thoren (1979) (above); for comparison, Wittich's diagram for the superior planets from Vatican f. 207v (below).

Tycho intended to carry out this goal nor whether, in fact, he did so on that occasion. As a result, historians such as Christine Schofield,[133] Kristian P. Moesgaard,[134] and more recently, Victor Thoren,[135] have been left to conjecture about what Tycho was *presumably* doing in the early 1570s based upon a 1585 drawing that appears to pertain to the 1574 oration. In Thoren's reconstruction (Fig. 7), *T* is the resting earth, *C* is the center of motion for point *E*; in turn, *M* travels uniformly about *E* to generate the famous equant motion while the planet *P*, a superior planet, takes one earth year to circumnavigate *M*. By defining the eccentricity *TC* as three times the epicycle radius *EM*, Tycho imported Copernicus' equantless mechanism into his theory for the superior planets while deferring to the natural philosophers on *T*, the Earth, which remains at rest.

Now, even if one knows how to eliminate the equant, such knowledge does not force a heliocentric reorganization of the planets. In 1574 Tycho was still a Ptolemaic astronomer who treated the planets independently of one another. The question at issue is what caused him to introduce sun-centered spheres and to produce thereby a new world scheme.

The immediate cause, as John Christianson showed, was Tycho's early effort to find an orbit for the comet of 1577.[136] In his brief German treatise of 1578 on the comet, prepared for an audience primarily interested in the political meanings of celestial events, Tycho told his patron, King Frederick II of Denmark, that the comet was probably moving in the sphere of Venus and that some people believe that Mercury and Venus encircle the sun. Tycho knew that in the planetary version of Martianus Capella, Mercury and Venus were circumsolar.[137] The Capellan arrangement was available to him in three different texts: Copernicus' Book I, chapter 10 (". . . well known to Martianus Capella, who wrote the *Encyclopedia* and to certain other Latin authors. For they believed that Venus and Mercury went around the Sun in the middle . . ."); in an account of Capella's work included in an edition of Pliny, Tycho's copy of which contains one of his own rare annotations at precisely this place[138]; and by far the most visually striking, an astronomical textbook published in 1573 by the Cologne professor of mathematics, Valentine Naibod. Tycho's copy of Naibod's book is bound with his initials and the date 1576.[139] But there exists no evidence that either the Capellan texts or the cometary treatise had provoked the construction of a new world picture. Thus our problem narrows further: What happened between Tycho's composition of his vernacular treatise on the comet in 1578, with its reordering of the inferior planets, and the period 1583/84, when Tycho claims to have discovered his world system?

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[133] Jones Schofield, *Tychonic World Systems* (supra n. 2).

[134] Moesgaard, "Copernican Influence" (supra n. 2), pp. 31–55.

[135] Thoren, "The Comet of 1577" (supra n. 2).

[136] J. R. Christianson, "Tycho Brahe's German Treatise on the Comet of 1577: A Study in Science and Politics," *Isis*, 70 (1979), 110–40.

[137] Bruce S. Eastwood, "'The Chaster Path of Venus" in the Astronomy of Martianus Capella," *Archives Internationales d'Histoire des Sciences*, 32 (1982), 145–58.

[138] See pp. 453–54 in *In C. Plini de naturalis historia* (Basel, 1531), Prague University Library shelf mark 7 B 27 = M7.

[139] *Primarum de coelo et terra institutionum quotidianarumque mundi revolutionum libri tres* (Venice, 1573), Prague University Library, shelf mark 5 J 2 = M28. See Westman, "Three Responses" (supra n. 2), pp. 322–23.

One significant event was the arrival of Paul Wittich on the isle of Hven in the summer of 1580. Like Tycho, Wittich shared the Wittenberg program of transforming Copernican models into geostatic mechanisms. But, unlike Tycho, Wittich had worked out exactly how to make these transformations for all the planets. As we have seen, his copies of *De revolutionibus* contain not only his own notes and additional diagrams bound into them but also a preliminary overlay of annotations copied directly out of Erasmus Reinhold's personal copy of the same book. Whatever previous exposure Tycho may have had to Reinhold's work, Wittich's arrival with these rich commentaries was clearly a moment of great opportunity.

A particularly important text, which Reinhold annotated heavily, is Book III, chapter 20, where Copernicus embodies the results of his struggle with the change of eccentricity and irregular motion of the earth's apsidal line. The problem is of special significance because the heliocentric motions of the other planets can scarcely be found without a theory of the sun's motion. The kind of transformations shown by Copernicus for the sun, and worked through again by Reinhold, were the basis for Wittich's study of the planetary models found in his Vatican notes.

Now it is interesting that Wittich undertook this study quite self-consciously; evidently he intended to show these notes to others, as the use of second person singular on folios 199 and 203 indicates. One of the diagrams, f. 207v, is precisely the same as the one that Thoren imagines Tycho to have drawn in 1574. Our suggestion is that only in 1580, under Wittich's tutelage, did Tycho learn exactly how to make these transformations for each of the planets. What Tycho might have wished to do in 1574, Wittich could have taught him on Hven in the summer of 1580. Wittich knew well the alternative placements of the epicyclets that would be needed for any detailed and systematic assembly of all the orbits into a combined geoheliocentric arrangement.

But recall Wittich's last Vatican diagram—the culmination of a fortnight's study of Copernicus' planetary hypotheses.[140] This diagram is unusual in two respects. Unlike all the other figures, this one, drawn on 17 February 1578, is a departure from the precise second-order models that appear earlier. The diagram places the individual hypotheses together into a single arrangement, although without specification of parameters. Secondly, such unified combination diagrams that show several planets with at least some epicyclic detail are distinctly rare in the sixteenth century. Wittich's semi-geoheliocentric scheme still differs, however, in one critical way from a Tychonic-type geoheliocentric system. Like Tycho, Wittich adopted a Capellan ordering for Venus and Mercury; but, unlike Tycho, he showed Mars, Jupiter, and Saturn as circumterrestrial and riding on their annual epicycles. We can see, with the advantage of hindsight, that Wittich failed to make the entire system coherent throughout by drawing radial lines from the sun to the planets and thereby completing the parallelograms. On the basis of this retrospective reconstruction, we can draw an inference: Wittich probably realized that such a scheme, lacking any interpenetration of circles, was not allowed by the parameters. Wittich produced, instead, a drawing carefully made to allow the circles barely to touch, but not to interpenetrate. It has all the marks of an astronomical draftsman who still honored the concept of solid crystalline spheres, and who was thus unable to see any warrant for adding the parallelograms to an arrangement that was schematic and not to scale. Nevertheless, he drew it so that one Copernican fact stared everyone in the face: each of the three epicycles for the major planets was a mirror of the orbis magnus of the sun. Indeed, the diagram is labeled "from the Copernican hypotheses accommodated to the immobility of the earth."[141] All the radius vectors (to speak in modern terms) were mysteriously, though not mechanically, linked in tandem. With this diagram Wittich could exhibit and emphasize the parallel lines in the system, evident when he drew the entire "sphere of revolutions" but lost when he constructed the planetary "hypotheses" individually.

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[140] Vatican f. 210v—see Appendix I.

Did Wittich show his diagrams to Tycho and admit that he was stuck in trying to show these congruences in a scale diagram? We cannot answer concerning the latter admission, but recently we discovered a remarkable letter from Dudith to Praetorius that sheds unexpected light on the transactions between Tycho and Wittich. "A certain friend of mine with whom Wittich spoke," wrote Dudith (probably referring to Hagecius),

> showed me a diagram of his not much different from those new hypotheses of Tycho, save for that absurdity (which you called attention to there) about the collision of the planets [de collisione planetarum], which here appears to be absent. I want to add it below so that I might learn from you whether it is worthy of praise. I hear that he, being only human, boasted that he communicated this diagram to Tycho. And if you can, send me your opinion on both [drawings].[142]

The diagram in Dudith's letter grossly simplified the one on Vatican f. 210v. The Capellan arrangement was shown for the inner planets, and the outer ones remained geocentric, with the epicycles omitted (Fig. 8). The Vatican drawings "communicated to Tycho" displayed more fully the tension between Wittich's geometrical ingenuity and his untenable avoidance of the "collision of the planets." Not everyone understood the difficulties in Wittich's diagram. Apparently Dudith did not, and Praetorius' notebooks show that several years later he was still experimenting with a Vatican-type system, devoid of any "absurd" collision of the spheres (Fig. 9). And Ursus published a geoheliocentric scheme in 1588 not much different from Wittich's. To the details of that system and the controversies provoked by it we now turn.

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[141] *Ibid.;* note our discussion of "hypotheses" on pp. 82 and 138.

[142] Dudith to Praetorius, 25 January 1589, Esztergom, p. 93: "Ostendit mihi amicus quidam meus cum quo Wittichius versabatur, Diagramma eius non multum absimile ab illis novis Tychonis hypothesibus nisi quod absurdum illud, quod tu in eo notasti, de collisione planetarum hic abesse videtur; volui subscribere ut ex te discerem ecquid laude dignum habeat. Audio illum, ut erat homo, gloriatum fuisse Tychoni se hoc Diagramma communicasse. Tu utriusque, si lubet, examen mihi mitte."

IIIB. A Theft in the Castle?

Tycho's geoheliocentric system had no sooner issued forth from his own presses at Uraniborg early in the spring of 1588 than he learned that Nicholas Reimarus Ursus had published, shortly thereafter, a description of a cosmology closely resembling his own.[143] The world system of Ursus' *Fundamentum astronomicum* differs in at least two respects from Tycho's: the earth has a daily rotation on its axis; and the orb of Mars around the Sun does not intersect the orb of the Sun around the Earth (Fig. 10). These differences were of no consolation to Tycho who was now convinced of what he had only suspected earlier: an untrustworthy servant in the employ of a fellow nobleman had stolen the essential idea of his world system from him. From this turn of events he never quite recovered. The ordering of the heavens had become a matter of honor in a rivalry where priority was the prize.[144]

It was not until 1596, in his *Epistolae astronomicae*, that Tycho first published his charges of plagiarism against Ursus. But the richest details of the episode are not included in this volume; they appeared instead in a letter written to Thaddeus Hagecius, Imperial Physician to Rudolph II from 1576 until his death in 1600. This letter was composed in 1592, just after Tycho learned that Ursus had joined Hagecius at the court in Prague as Imperial Mathematician. The main outlines of the Ursus Affair, most

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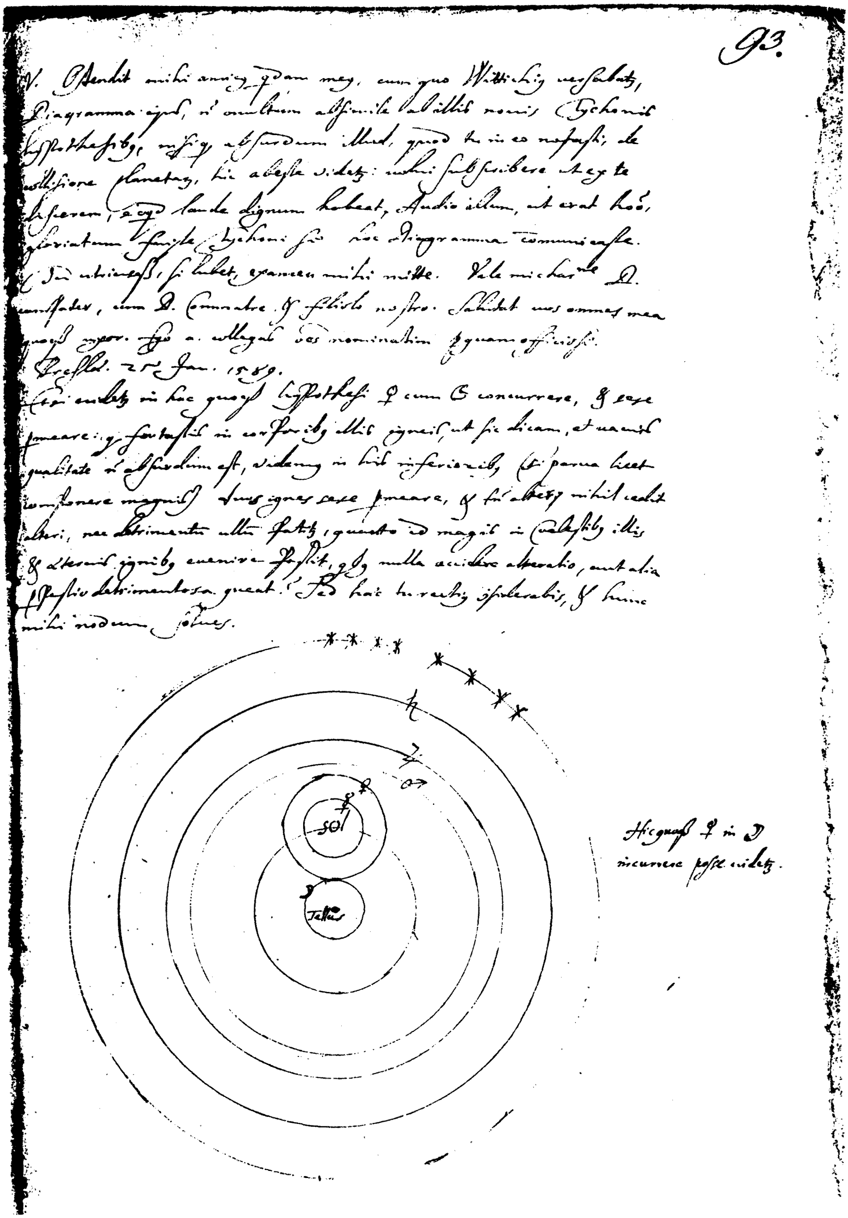
[143] Nicolaus Raymarus Ursus, *Fundamentum astronomicum; id est, Nova doctrina sinuum et triangulorum* (Strassburg, 1588). According to Rosen, *Three Imperial Mathematicians*, p. 14, the book was published on 31 July 1588, but actually this is only a terminus a quo since that is the date of the dedicatory epistle. On 30 October 1588 Andreas Dudith wrote to Praetorius, "Have you seen the *Fundamentum astronomicum* of Nicolaus Raimers Ursus published in Strassburg? Is it better than expected?" (Esztergom, p. 72: "Vidistine Argentorati editum Nic. Raimari Ursi ejusdem Fundam. Astronomicum? Praestatne quam promittit?"). This seems to imply that the book had been published although Dudith had not seen it, and that he assumed that Praetorius in Altdorf had probably seen it by then.

[144] Competition for patronage and reputation often resulted in contentious personal disputes and charges of plagiarism between humanistic academics who fought over interpretations and authorities in classical studies (Anthony Grafton and Lisa Jardine, *From Humanism to the Humanities*, [London, 1986], pp. 62–67); note for example the fierce polemical struggle between the low-born Nicolo Tartaglia and high-ranking Girolamo Cardano over the solution of the cubic equation (Oystein Ore, *Cardano the Gambling Scholar* [Princeton, 1953; reprint New York, 1965]).



93.

S. Ostendit mihi amicus quidam meus, cum quo Wittichius versabatur,
Diagramma ipsius, non multum absimile tabellis novis Tychonis
hypothesibus, nisi quod absurdum illud, quod tu in eo notasti, de
collisione planetarum, hic abesse videtur: nihil subscribere neque te
[illegible], neque laude dignum habeat. Audio illum, ut erat homo,
gloriatum fuisse Tychoni se hoc diagramma communicasse.
Tu utrumque, si libet, examen mihi mitte. Vale mi char^me D.
Compater, cum D. Commatre et filiolo nostro. Salutat vos omnes mea
quoque uxor. Ego a collegis vos nominatim quam officiosissime.
Wratisl. 25 Jan. 1589.
Ut videtur in hac quoque hypothesi ♀ cum ☉ concurrere, et sese
permeare: quod fortassis in corporibus illis igneis, ut sic dicam, et eiusdem
qualitatis non absurdum est, videmus in his inferioribus (si parva licet
componere magnis) duos ignes sese permeare, et sibi alterum nihil cedit
alteri, nec detrimento ullo afficit, quanto id magis in caelestibus illis
et aeternis ignibus evenire possit, quibus nulla accidere alteratio, aut alia
passio detrimentosa queat. Sed haec tu rectius expendes, et hunc
mihi nodum solves.

Hic quoque ♀ in ☉ incurrere posse videtur.

Fig. 8. Andreas Dudith to Johannes Praetorius, 25 January 1589, showing the planetary system attributed to Wittich. (Courtesy of the Archiepiscopal Library, Esztergom, Hungary.)

of which are now fairly well known, still bear careful review. What we know of the charges and counter-charges comes down to us through three principal sources, each with a special interest in how the episode should be recounted.[145] These sources are Tycho himself, Ursus, and Johannes Kepler—the latter recruited by Tycho to defend his honor.

Tycho's "Legal Brief" on the Ursus Affair

Reconstructing the crowded and uncertain events of 1584–86 is difficult. However, our frustration can hardly match the exasperation that Tycho himself must have experienced. He believed that his ideas were stolen during Ursus' visit to Uraniborg castle in September 1584. In letters to various noble friends and professors, Tycho communicated one basic account, but with a shifting embroidery of detail that suggests an underlying uncertainty about what really happened in his own castle. In what follows, we present the evidence available to us.

Tycho's first version occurs in a letter written 4 November 1588 to Henry Van Den Brock, professor of mathematics at Rostock. According to this account, Ursus arrived in the service of a Danish aristocrat, Eric Lange. During his visit Ursus noticed some of Tycho's papers lying about and proceeded to copy some of them. Tycho's assistants observed Ursus' behavior and promptly reported it. Tycho then demanded that the papers be returned but, upon recovering them, he found none containing diagrams of his world system. This caused him to speculate that Ursus "could have hidden it elsewhere or memorized it, when perhaps the opportunity for copying it was not available."[146] Finally, Tycho makes it clear that Ursus had not understood the Tychonic system properly because in his diagram there was no intersection of the spheres of Mars and the sun.

A few months later, on 21 December 1588, Tycho provided a somewhat more detailed version of the same episode to Ursus' original patron, the governor of Holstein, Heinrich Rantzau:

> While I was having a jolly good time with my close friend Eric and certain other nobles who were here with him, that crook secretly copied quite a few things that I had devised with much labor and care. He sketched the design and arrangement of all the instruments that were then in service. He removed many other things that he could examine, pretending nevertheless that he was doing none of these things . . . After I had got wind of his cunning, however, I arranged for someone else to recover a large part of what he had stolen, and I still have it. I see now that he sketched or else committed to memory more than I recovered.

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[145] For discussions of the Ursus Affair, see Jardine, *Birth of HPS* (supra n. 2), pp. 7–79; Rosen, *Three Imperial Mathematicians* (supra n. 2); Jones Schofield, *Tychonic World Systems* (supra n. 2), pp. 108–36; Dreyer, *Tycho Brahe*, pp. 183–84, 268, 273, 288, 290, 304, 312.

[146] Brahe to Brucaeus, 4 November 1588, *TBOO*, VII, p. 149:19–21; translation from Rosen, *Three Imperial Mathematicians* (supra n. 2), p. 32.

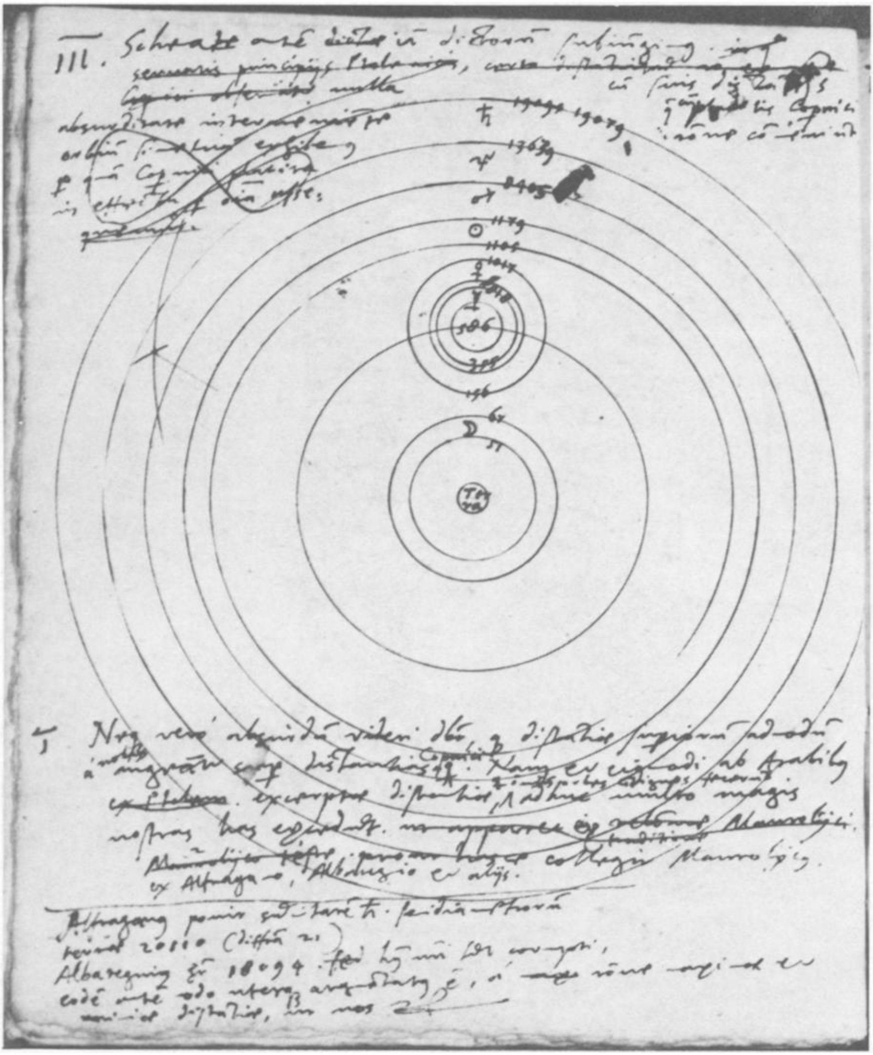

Fig. 9. Johannes Praetorius' planetary system from 1594, in his *Compendiosa enarratio Hypothesium Nic. Copernici, Earundem insuper alia dispositio super Ptolemaica principia*. Erlangen MS 814, f. 100v. (Permission of Erlangen University Library.)

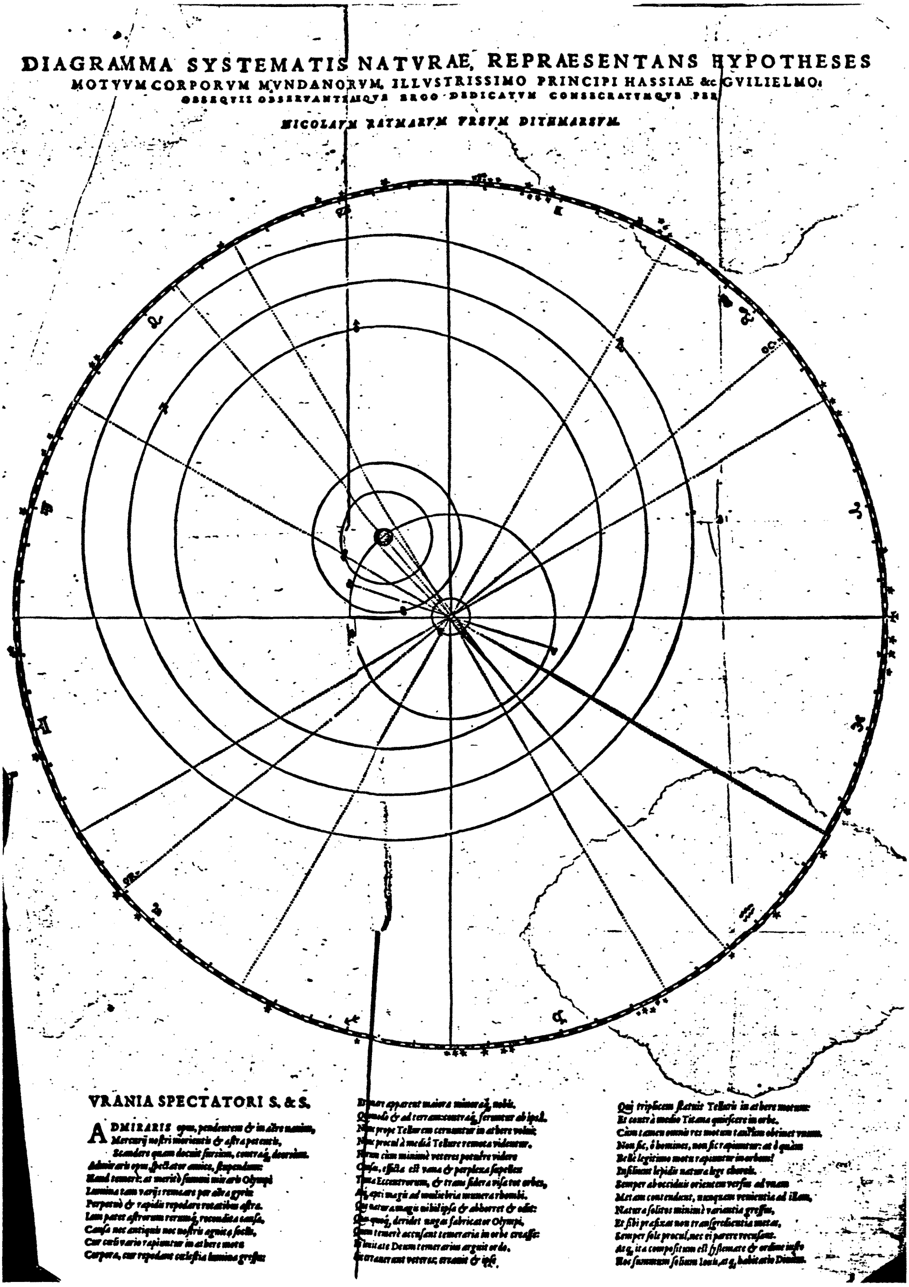
DIAGRAMMA SYSTEMATIS NATVRAE, REPRAESENTANS HYPOTHESES
MOTVVM CORPORVM MVNDANORVM, ILLVSTRISSIMO PRINCIPI HASSIAE &c GVILIELMO:
OBSEQVII OBSERVANTIAEQVE ERGO DEDICATVM CONSECRATVMQVE PER
NICOLAVM RAYMARVM VRSVM DITHMARSVM.
VRANIA SPECTATORI S. & S.

Fig. 10. Ursus' geoheliocentric system, from his *Fundamentum astronomicum* (1588). (Permission of Houghton Library, Harvard University.)

> For, as far as I know, this rearrangement of the hypotheses never occurred to anybody before me.[147]

Tycho then added another conjecture about the manner in which Ursus had managed to steal his cosmic hypotheses. Eric Lange had asked his host for an explanation of the planets' motions according to both the Ptolemaic and Copernican hypotheses. Tycho obliged by drawing both on the table, followed by a depiction of his own system. As Tycho reported the episode, Eric

> noticed that I was reluctant to do so [i.e. draw the Tychonic system] while his Dithmarschan servant was standing around and watching, (for I had previously indicated to him that from the fellows' habits and appearance I had surmised what type he was). Sending him outside to do something else, Eric obtained from me what he wanted. I sketched for him my hypotheses, too, drawn in a general and brief manner, but I erased them right away.[148]

Tycho's precautions were insufficient, for while he was drawing pictures for Eric, Ursus was wandering around the castle:

> Thus, among my papers lying on a window sill he came across a certain sketch of this arrangement of the heavenly motions which, through some negligence or other, was drawn in such a way that Mars' sphere completely enveloped the sun's. Being incorrect, this [paper] was discarded and set aside as unsuitable and out of line. Yet he seized upon it as the true and correct sketch. Later on, he either drew it secretly or committed it to memory.[149]

Further on, Tycho described the defective drawing as "erroneous, drawn on a whole, unfolded sheet."[150] Still another reference to the "erroneous diagram" occurs in a letter from Tycho to the Landgrave's astronomer, Christoph Rothmann, on 21 February 1589: "In drawing Mars' orb completely enclosing the sun's, he copied a certain incorrect diagram which had been drawn in this way through some inadvertence and, for that reason, was thrown away somewhere among my papers as inaccurate. I still have it in my hands because it was tracked down in order to make this matter absolutely clear."[151]

But Tycho's problems with Ursus were not over; he soon received disconcerting news from Prague. In letters now lost, Thaddeus Hagecius praised Ursus' character and mentioned his appointment as Imperial Astronomer in 1591. Tycho questioned whether Hagecius had not been taken in by Ursus' "crafty and cunning words" and provided, in the course of his reply, the most comprehensive story of the Ursus affair. His epistle is, in fact, effectively a legal brief. Although inconclusive on the exact details of Ursus' deed, Tycho's letter of March 1592 is so important for reconstructing the entire mystery that we present it here virtually in full.[152]

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[147] Brahe to Rantzau, 21 December 1588, *TBOO*, VII, p. 387:26–37; translation slightly modified from Rosen, p. 39.

[148] *Ibid.*, p. 388:1–9; Rosen, p. 40.

[149] *Ibid.*, p. 388:11–17; Rosen, p. 40.

[150] *Ibid.*, p. 388:24–25; Rosen, p. 41.

[151] Brahe to Rothmann, 21 February 1589, *TBOO*, VI, p. 179:38–42.

As usual, Tycho opens the now familiar account with a scene of revelry and drink. His noble friend Lange has arrived with a retinue of "barons and noblemen." Lange had heard "the opinion dropped from my lips that neither this theory nor that one conforms to the truth, but a far more suitable and probable theory can be devised." Tycho has set a stage for himself: he appears as the wise prince, explaining the universe to another of his class. Ursus' credibility is impugned throughout by associating him, through sarcasm and parody, with lower animals and social classes.

> Seizing a piece of chalk, I drew on the table for my friend Eric the Ptolemaic as well as the Copernican speculations about the celestial motions and I exposed the absurdities of both. When he asked if there was any third suitable arrangement, I drew it generally yet succinctly, and partly explained my invention for him. Then we erased it as far as could be done (for it was sketched on a green cloth thrown over the table). But afterward that long-nosed Ursus, sniffing that we had hidden this from him, conceived some idea of our hypotheses either from the traces left on the tablecloth, or from a certain paper that used to be in my study where it had been thrown with other scrap, or, from some one of my students who perhaps knew of it, or, finally, from somewhere else.
>
> Not long afterward he was dismissed by Eric on account of his tasteless arrogance and stupid conduct. Later, passing through Holstein and arriving in Magdeburg at the home of that most learned man George Rollenhagen,[153] the rector of a primary school, he tossed out a great many astonishing claims about the discovery of this hypothesis, which he falsely and arrogantly appropriated to himself. But, when Rollenhagen, not inexperienced in the mathematical arts, asked how to explain the retrogradations and stationary points of the planets, he was unable to extricate himself. Thereupon Rollenhagen caught on that Ursus was not the originator of this discovery. And, not long afterward, he reported this in letters to the most noble Lord Heinrich Rantzau and to me. Thus, he first exposed the theft long before the Bear's feeble and inadequate *Fundamentals* were scraped together, or rather, very presumptuously stolen from various authors.
>
> All those days with Eric and other noble friends, while I indulged in geniality rather than ingenuity (as the saying goes) Ursus secretly made a survey and examined carefully many other things of mine; he copied down much and committed other things to memory which afterward he was not embarrassed to publicize as his own (for such is his shameful nature). He revealed such things as the shortened computation of triangles through the use of prosthaphaereses, the in-

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[152] Brahe to Hagecius, 14 March 1592, *TBOO*, VII, 321–26; our translation covers pp. 322:11–325:27 and 326:1–13. After we had made a preliminary translation, Rosen's *Three Imperial Mathematicians* (supra n. 2) appeared, and we have profited from a comparison with his version on his pp. 266–78.

[153] Tycho is still somewhat uncertain at this stage whether Ursus is the only one who might have stolen something from him: "Rollenhagen writes that he obtained the design of this hypothesis by way of this servant. For I would like to know whether he was Ursus or someone else. In fact, I know that none of my students who worked for me up to now in matters of astronomy left here secretly without my knowledge or permission." (Brahe to Rantzau, 21 December 1588, *TBOO*, VII, p. 389:10–14). Translation modified from Rosen, *Three Imperial Mathematicians* (supra n. 2), pp. 43–44.

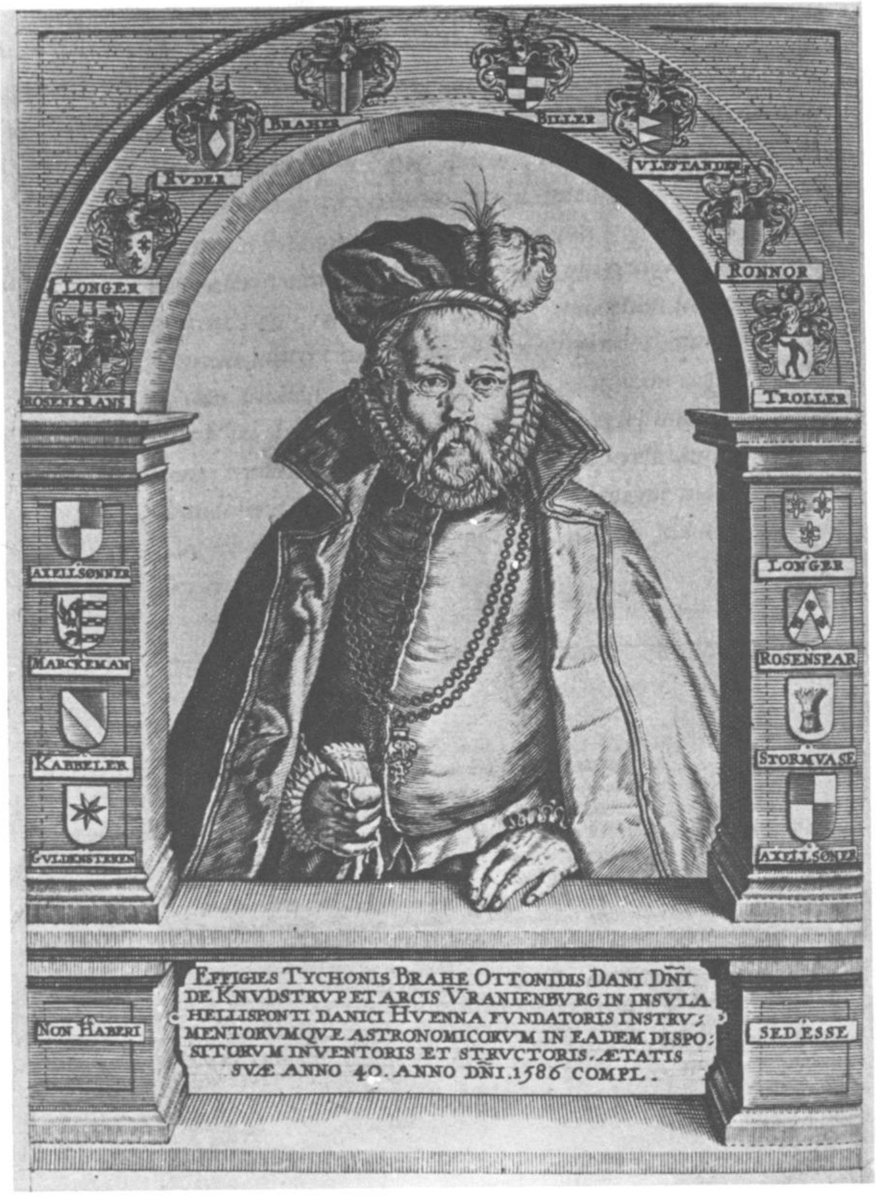
BRAHER
BILLER
RVDER
VLFSTANDER
LONGER
RONNOR
ROSENKRANS
TROLLER
AXELSØNNER
LONGER
MARCKEMAN
ROSENSPAR
KABBELER
STORMVASE
GVLDENSTERN
AXELSØNER
EFFIGIES TYCHONIS BRAHE OTTONIDIS DANI DÑI
DE KNVDSTRVP ET ARCIS VRANIENBVRG IN INSVLA
HELLISPONTI DANICI HVENNA FVNDATORIS INSTRV:
MENTORVMQVE ASTRONOMICORVM IN EADEM DISPO:
SITORVM INVENTORIS ET STRVCTORIS. ÆTATIS
SVÆ ANNO 40. ANNO DÑI. 1586 COMPL.
NON HABERI
SED ESSE

Fig. 11. Tycho Brahe's portrait with the arms of his forebears, found in some copies of his *Epistolae astronomicae* (1596). (Courtesy of Harvard College Library.)

struments (both sextant and quadrant), how to improve the positions of the fixed stars using Venus as intermediary to the sun,[154] and other similar topics.

At this point in his enumeration of Ursus' thefts, Tycho introduces Wittich. He believes that Wittich has transmitted some of his ideas to the court of Hesse-Cassel.

As far as the short-cut trigonometry is concerned, long ago when Wittich was here I freely and generously discussed this and we mutually communicated what was found by him and what was found by me on this subject. However, after Wittich returned to his own country, he journeyed from there to the illustrious lord Wilhelm, Landgrave of Hesse, where he remained for some time. There he conveyed to the Landgrave's instrument maker, Joost Bürgi[155] (uneducated but at least skilled in making mechanical devices) all about the mysteries of the triangles that we had so carefully unlocked, and spoke openly as well about the construction of my instruments and about the idea therein of the divisions and sight-holes, so that the Landgrave was soon able to have built a sextant as well as a quadrant that were copies of mine (although Wittich did not acknowledge that they were). With these he could then obtain better and more precise observations than heretofore, about which you will learn from the astronomical letters passing between us.

Although Wittich is also implicated in a theft, he receives much kinder treatment than the low-born Ursus; it is the latter who stands accused of passing a description of Tycho's world system to the Landgrave. Indeed, from personal conversations with Rothmann in 1590, Tycho learned that Ursus benefited from Wittich's knowledge, both directly and through Bürgi.

After the departure of Wittich, Ursus, who never stayed long in one abode or den (perhaps in an imitation of the bears of the forest), scurried to Cassel, where he offered my hypotheses as his own to the Landgrave. But when they tried hard to fashion these into a clockwork model, although there was a sufficiently skilled mechanical craftsman, they could not make it work before Rothmann came in and incorporated some details from Copernicus. For that Bear ripped off only the more general parts as usually happens to those sneak thieves who repeatedly abandon untouched certain useful things because of their fear and trembling consciences. Furthermore, he obtained the method for observing the positions of the heavenly bodies, which he had partly seen here, some disclosed to him by Wittich, and then a more complete explanation from my letters sent to the Landgrave or his mathematician [Rothmann], which that fellow drank in more fully. What he had chiefly obtained from the aforementioned Joost Bürgi (although it turned out very badly) were the proof of the short-cut trigonometry and its numerical examples that Wittich had left to him. In place of remuneration (and for other things as well), he [Ursus] translated the whole of Copernicus into German.[156] All of this and more Christoph Rothmann indicated to me not so much through letters as here two years ago when he was sent by the Landgrave to look over my instruments.[157]

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[154] Ptolemy had used the moon as an intermediary for connecting the coordinates of the sun and stars; Tycho's innovation was to use Venus as the intermediary, which was more accurate as a point source and whose position was better known.

[155] For further details of Joost Bürgi, see von Mackensen (supra n. 60) and see also J. H. Leopold, *Astronomen Sterne Geräte: Landgraf Wilhelm IV. und seine sich selbst bewegenden Globen* (Luzern, 1986).

Next Ursus "snuck off" to Strassburg, where he engaged in new mischief. Tycho misses no opportunity to blacken Ursus' character and, thus, his credibility.

Afterward in order to earn money, he tutored students for some time in those things he had seen or learned or stolen here and at Cassel, and finally, he did not hesitate to publish these ideas in his own name, with an excessively pompous and presumptuous title, even though mostly they were flawed or deficient.[158] With everything he revised, he there dedicated various parts of this pastiche in a novel and tasteless way to various mathematicians known to him only by name, but passing in silence over me alone (for which I congratulate myself in that he did not defile my name with his thefts).[159] If others had then realized that he had some connection with me, his fraud and plagiarism would have been detected much earlier, since everything he put forth there originated in my workshop, except that he spoiled it or did not use it correctly.

Perhaps doubting that Hagecius will accept his story at face value, Tycho sends along a dramatic document, now unfortunately lost.

Now, for you to be certain that this is the way the affair occurred, especially regarding the framing of my hypotheses, I am sending to you the very piece of paper that had been thrown away (which I referred to earlier) and from which he [Ursus] doubtlessly took this idea when he was here. At the same time when Rollenhagen first warned me about the plagiarism, one of my students brought me the sheet that had been sought among my various papers, saying that this particular one was lying in open view in my study among other papers when that Bear was here. Thus he could easily have gotten the idea that he published as his own. It is sufficiently proved that what he falsely advertised as his own he obtained here, if for no other reason than that through some negligence this old sketch includes the solar orb entirely within the orb of Mars. For that very reason I had thrown out this paper as completely useless. Likewise, by imitating this sketch, these orbs are incorrectly drawn in his diagram. As for the other things, he patched them on in a flimsy way to suit his fancy. In any event, I definitely want to have this piece of paper returned to me.

If that document was not sufficient, Tycho also has a personal report from one of his *trusted* assistants. Being trustworthy, he cannot help but add a new attribute to the previous estimate of the Bear's unreliability: his stupidity.

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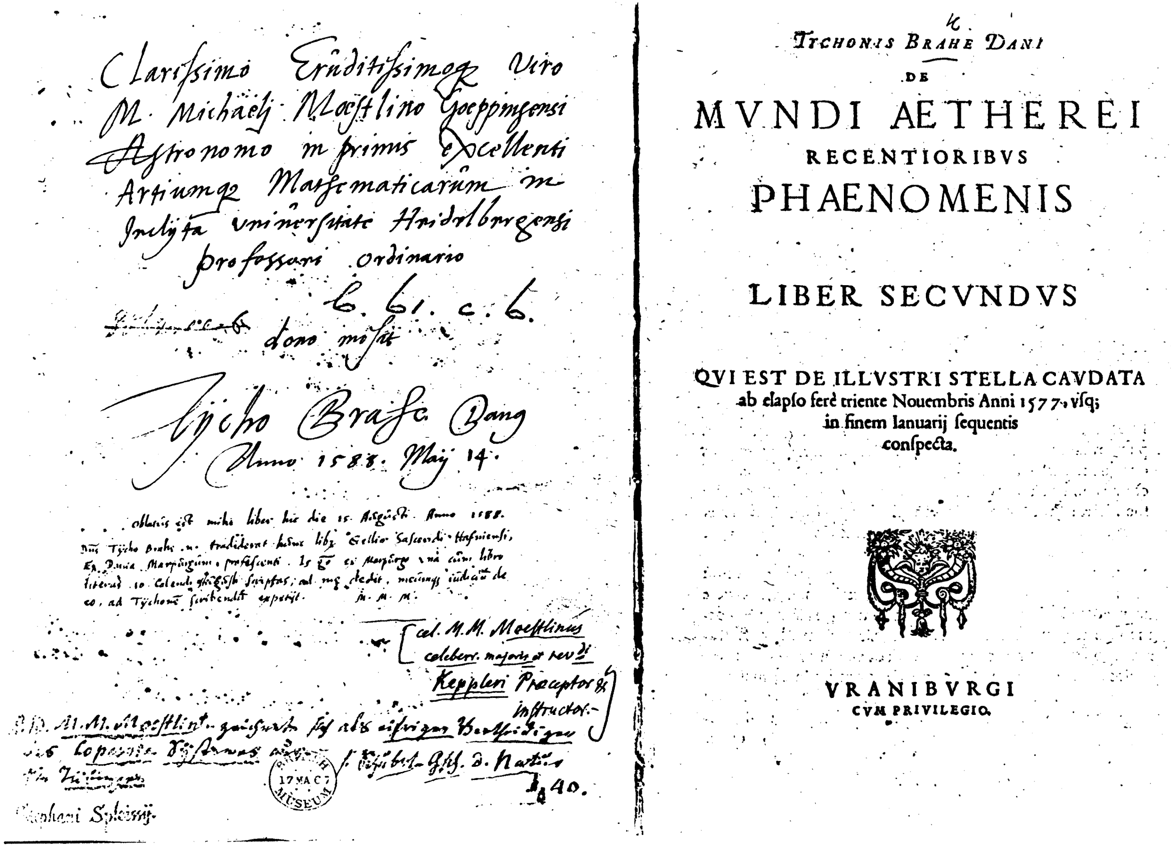
[156] See Edward Rosen, "The Earliest Translation of Copernicus' 'Revolutions' into German," *Sudhoffs Archiv*, 66 (1982), 301–305.

[157] Rothmann's visit to Tycho took place 1 August to 1 September 1590. *TBOO*, IX, pp. 89, 91.

[158] Ursus, *Fundamentum astronomicum* (supra n. 143).

[159] Of Ursus' diagrams alluded to by Tycho, one dedicated to Wittich is on f. 16v; for some of the other dedicatees, see Rosen, *Three Imperial Mathematicians* (supra n. 2), pp. 71, 80.



Clarissimo Eruditissimoque Viro
M. Michaeli Maestlino Goeppingensi
Astronomo in primis Excellenti
Artiumque Mathematicarum in
Inclyta universitate Heidelbergensi
professori ordinario
6. 61. c. 6.
dono misit
Tycho Brahe Danus
Anno 1588. Maij 14.

Oblatus est mihi liber hic die 15. Augusti. Anno 1588. Dns Tycho Brahe .n. tradiderat hunc libr. Gellio Sascerido Hafniensi, Ex Dania Marpurgum proficiscenti. Is ergo ex Marpurgo vna cum libro literas 10. Calend. [illegible] scriptas, ad me dedit, meumque iudicium de eo, ad Tychonem scribendum expetijt. M. M. M.

cel. M. M. Maestlinus
celeberr. majoris et rev. di
Keppleri Praeceptor et
instructor.

M. M. Maestlin [illegible] als eifrigen Verteidiger des Copernic. Systems [illegible] [illegible] d. Natur [illegible] 40.

Stephani Spleissij.

BRITISH MUSEUM 17 MA C 7

TYCHONIS BRAHE DANI
DE
MVNDI AETHEREI
RECENTIORIBVS
PHAENOMENIS
LIBER SECVNDVS
QVI EST DE ILLVSTRI STELLA CAVDATA
ab elapſo ferè triente Nouembris Anni 1577. vſq;
in finem Ianuarij ſequentis
conſpecta.
VRANIBVRGI
CVM PRIVILEGIO.

Fig. 12. The presentation copy of Tycho's *De mundi aetherei recentioribus phaenomenis,* with his autograph inscription to Michael Maestlin. The May 14, 1588 date shows that the distribution of Tycho's book had begun three months before Ursus' *Fundamentum astronomicum* was completed. (Courtesy of the British Library.)

The aforementioned Gellius Sascerides, who was a member of my household for eight years, departed for Italy, stayed a while in Germany, and then passed through Strassburg. There he discovered that Bear. [On the spot] he openly told him to his face that his *Fundamentals* had been scraped and thrown together from other's bricks, that he falsely attributed to himself the discovery of these hypotheses, which are entirely mine, and that for some years earlier he [Gellius] had known about it from me. That he indeed published this gross error in the diagram about the orb of Mars completely surrounding the solar orb proves that he did not understand these fundamentals, much less that he was the author of this discovery. And he [Gellius] objected that very many other things were snatched earlier from me. In fact, since he is filled with impudent craftiness, he was not afraid to swear falsely that he did not take this hypothesis from me, but at the very least Gellius forced him to confess that he did not correctly understand it and wrongly represented the orb of Mars in it. Now I ask you, how could this very same person have discovered something, already found by another, that he did not understand properly or rather, that he corrupted? For it is always easy to add something later to another's discovery.

Gellius wrote to me about this matter from Strassburg and then also from Italy. These very letters are here enclosed and are to be returned to me here safely and securely.[160] You will understand from them what the situation is. Gellius is quite a young man; although he has passed his thirtieth year, he is especially learned in various sciences and also endowed with a singularly upright character and seriousness; he has a love of truth that he respects more highly than others—a love that he often heard very highly praised by me.

Next Tycho makes a new allegation: in spite of the publication dates, it is he who has priority in printing, and it is Ursus who took the discovery from him rather than vice versa (see Figure 12). He also reveals that at least one other person—the Scot Duncan Liddel—knew of his world system in advance.

If there were no other evidence, what would prove that he took this sketch from my invention by some trick or other, rather than my borrowing it from his scraped-together farrago, is that our *De mundi aetherei recentioribus phaenomenis liber secundus* had been printed long before his rhapsodic "Fundamentals" were published. Before they appeared, I had already thought up these hypotheses. To go to the heart of the matter, the celestial appearances themselves had thus impelled me. I had decided to hold this idea back for a comprehensive work on the reform of astronomy; nevertheless, I worried about both this Bear and someone else, a certain Scot who had become acquainted with it by conversations here, and who afterward taught it privately to his students in Rostock.[161] However, the Scot did

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[160] Although much remains of Tycho's correspondence, the surviving material is sporadic and much is lost, including these letters from Gellius.

[161] The unidentified Scot is, of course, Duncan Liddel, who visited Hven in June 1587 (*TBOO*, IX, 55). Concerning Liddel, see the letter of 1 May 1607 from Johannes Caselius to John Craig in Duncan Liddel, *Ars medica* (Hamburg, 1607 or 1608); James Bruce, *Lives of Eminent Men of Aberdeen* (Aberdeen, 1841), based primarily on John Stuart, *A Sketch of the Life of Dr. Duncan Liddel, of Aberdeen, Professor of Mathematics and of Medicine in the University of Helmstadt* (Aberdeen, 1790); Peter John Anderson, *Notes on Academic Theses with Bibliography of Duncan Liddel* (Aberdeen, 1912); A. George Molland, "Duncan Liddel (1561–1613): An Early Benefactor of Marischal College Library," *Aberdeen University Review*, 176 (1986), 485–99.

> not deny it was my invention and with a clear conscience and in contradiction to that Bear, he testified that he got this idea here. So because of these and similar fears I decided rather advisedly and for good reasons to put these before other things in Book Two.

Finally, Tycho states that he has in his possession further of evidence of Ursus' crimes.

> As for trigonometry, you will see something about these teachings in the appropriate place in some of my volumes. Already very many years ago I wrote them down for my students, so that they could have the rules for easily making astronomical calculations. Our pamphlet of rules was lying open for teaching in our library on each table (so that nearly anyone could have a copy in his own hands); thus it was very easy at any time for this Bear to lick it up, like a deceitful parasite. But he could scarcely obtain their geometrical proofs, because I kept these separately with my more important writings; later he stumbled on them by chance from the Landgrave's instrument maker in Cassel (as I told you). Anyway, I have many more pages, written in his own hand, which he secretly copied out here and which he made up his mind to steal with the rest. . . .
>
> Finally, so that there may be no just pretext for his denials that he copied most of my papers here without my knowledge, I still have a whole bundle of them that he secretly copied by his own hand and was trying to take away with him. For, one day before he left here, I arranged with his master Eric to have them stealthily taken back at night when he lay buried in wine and sleep.[162] However, the person who was supposed to get them back was not clever enough so that he did not even find the stolen goods. Similarly Ursus himself did not get everything he wanted to carry away, whether you refer to his head or to his hands. Now if he persists in his evil doings and does not confess and repent his plagiarisms, but continues to excuse his perversity and lying, I shall have him publicly accused, convicted, and punished to the fullest extent of the law, as he deserves.[163]

Tycho's case is complete. He has dragged Ursus through the mud and has reduced him to the status of an animal. He appeals throughout to his own and to his assistant's unquestioned good character. He supplies the Emperor's Physician with the allegedly stolen diagram and numerous hypotheses about how Ursus might have accomplished the deed. But his efforts to demolish Ursus were evidently not sufficient, because Rudolph's Imperial Astronomer retained his position. And several years later, when Tycho himself arrived in Prague, he continued to pursue Ursus with legal means, although now, once outside his patrimonial network, this proved to be more difficult. "I am a foreigner here," wrote Tycho from Benatky Castle in March 1600. "I am not sustained, as I was previously in my native land, by the prestige of the nobility, and kinship and connections with the most outstanding men. Indeed, outside the Imperial Court here, I lead a sheltered life, unaware of what is being said about me anywhere at all. Nor do I in other respects willingly become involved in the affairs of others."[164]

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[162] Here Tycho is quoting Virgil, *Aeneid* II.265.

[163] Tycho Brahe in fact took legal proceedings against Ursus, and in the summer of 1600, Rudolf II directed the Archbishop of Prague to confiscate and burn every obtainable copy of his *De astronomicis hypothesibus*—see note 165 below.

Ursus' Account and Kepler's Interpretation

We turn now to Ursus' own story of 1597, which appeared in *De astronomicis hypothesibus,*[165] an insulting and satirical diatribe directed primarily against Tycho.[166] The positions ascribed by Ursus to his opponents are drawn from evidence published by Tycho the previous year in his *Epistolae astronomicae*, a kind of sourcebook of the controversy. Ursus claims to have discovered his world system in October 1585.[167] A few months later he visited the court of Wilhelm, Landgrave of Hesse Cassel, and as evidence for his early involvement with this system, Ursus cites a brass model of that planetary arrangement, no longer extant, which was cast in 1586 by Joost Bürgi, the Landgrave's clockmaker.[168] Ursus guesses (correctly) that Christoph Rothmann, the Landgrave's astronomer-in-residence, had informed Tycho about this model.

In spite of the fact that Ursus follows a general strategy of discrediting and defaming Tycho at every opportunity, he does not charge Tycho with plagiarizing his own system. Instead, he maintains something quite different: that Tycho "either did not know or pretended that he did not know" that his hypotheses were already anticipated by Copernicus and Apollonius of Perga.[169] In other words, he charges that everything contained in Tycho's system could have been extracted from a reading of certain passages in *De revolutionibus*, namely, III,25, V,3, and V,35. In those sections, Copernicus makes explicit reference to Apollonius of Perga, and Ursus is convinced that the Apollonian references in Copernicus constitute sufficient grounds from which to extract a geoheliocentric system. In short, Ursus reduces Tycho to having made a mere *textual* discovery. It is of no small interest that Ursus quotes precisely these passages, for it provides us with a valuable opportunity to observe just how Ursus himself read *De revolutionibus* and how he used the text to justify his charge that "my antagonists, . . . either did not read Copernicus or, in reading him, did not understand what they read."[170]

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[164] Brahe to Jessenius, 28 March 1600, *TBOO*, VIII, 282:25–29; translated by Rosen, *Three Imperial Mathematicians*, p. 260.

[165] Nicolaus Reimarus Ursus, *De astronomicis hypothesibus tractatus* (privately published, Prague, 1597). Because of Tycho's legal proceedings, the book is so scarce that Dreyer had not seen a copy of it when he wrote *Tycho Brahe* (see its note on p. 273), but in his personal copy (now owned by Owen Gingerich) he penciled in the statement that a copy was found in the Crawford Collection, Royal Observatory, Edinburgh. In America, there is a copy at Brown University and an incomplete copy in a private collection. Perhaps two dozen copies can be found in European libraries.

[166] And against two other rivals as well, Christoph Rothmann and Helisaeus Roeslin (1548–1606).

[167] Ursus, *De astronomicis hypothesibus*, sig. Aij. Jardine's "October 1584" is a slip: *Birth of HPS*, p. 36.

[168] *Ibid.*, sig. Aijv.

[169] *Ibid.*, sig. A[iv]:27.

Ursus' most crucial reference occurs in *De revolutionibus* III,25, in a chapter entitled "Calculating the Apparent Movement of the Sun," where Copernicus discusses whether the sun or the center of the earth's orbit is the fixed center of the universe; in the latter case, the sun would actually have a small, slow movement.[171] There Copernicus wrote:

> In this way the computation of the apparent sun is obtained through the motion of the earth in agreement with ancient and modern methods, so that in addition the future motion has presumably already been foreseen.
>
> Nevertheless, I am also not unaware that if anybody believed the center of the annual revolution (of the Earth) to be stationary as the center of the universe, while the sun moved with two motions similar and equal to those which I explained in connection with the center of the eccentric [III,20], all the phenomena would appear as before—the same figures and the same proof. Nothing would be changed in them, especially the phenomena pertaining to the sun, except the position. For this reason there will still remain a doubt about which of these two positions is occupied by the center of the universe, as I said ambiguously at the beginning that the center of the universe is in the sun [I,9, I,10] or near it [I,10]. I shall discuss this question further, however, in my treatment of the five planets.[172]

What are we to make of this passage? Can one truly "find" the Tychonic system here, as Ursus claims?

In a letter of May 1599, Johannes Kepler expressed a detailed opinion on Ursus' interpretation of this passage, addressing himself explicitly to the question of whether it supported Ursus' charges against Tycho:

> Ursus says that both his and Tycho's hypotheses were derived from the hypotheses of Apollonius of Perga made public long ago around the time of Christ. He bases his assertion on some passages in Copernicus in which [Ursus claims] Tycho's hypothesis is in part explicitly posited by Copernicus himself and in part ascribed to Apollonius of Perga (f. Dii). But what Copernicus says in these passages could not be further from what Ursus maintains. For he neither sets out Tycho's hypothesis—Ursus is mistaken in his reference—nor does he ascribe it to Apollonius of Perga. Ursus declares: 1, that he [himself] derived his hypotheses from elsewhere; 2, that he found it set out in Copernicus and attributed to Pergaeus; and 3, that it is the same as that which Tycho holds. So it follows that he copied it from someone else, which is just what Tycho claims.[173]

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[170] *Ibid.*, sig. Dijv.

[171] This passage, including Copernicus' promise to discuss the question later, caught the attention of several annotators including Reinhold and Maestlin. In Reinhold's and two related copies (one of which was later owned by Kepler), there appears a reference to ff. 143 and 158 as well as to Rheticus' *Narratio prima*. (See Gingerich, "Extended Errata List for Copernicus," [supra n. 115].)

[172] Ursus, *De astronomicis hypothesibus*, sig. Dii, quoting Copernicus *De revolutionibus*, III,25; quoted by Jardine, *Birth of HPS*, p. 55, who modified the translation of Edward Rosen, *Nicholas Copernicus: On the Revolutions*, vol. 2 of *Complete Works* (Warsaw and Cracow, 1978), p. 169.

[173] Jardine, *Birth of HPS*, pp. 60–61. Compare Kepler's statement in the *Apologia*: "Indeed, the fact that Ursus makes no mention of Ptolemy, who expounded Apollonius' opinion

Kepler continues:

> It should be noted that whoever revealed Ursus' hypotheses to him (lacking a little, which it is easy to make good) clearly held the same hypotheses as Tycho. But who is he? Ursus says he is Copernicus, and through him Pergaeus, and no one else besides. So no one apart from Pergaeus in Copernicus or Tycho is the author of the Ursine hypotheses. But I declare that neither Pergaeus nor Copernicus was the author of the Ursine hypotheses. So Tycho alone, and no one else, was the one who showed Ursus the way to his hypotheses. The confirmation of the case lies in a grasp of the true meaning of Copernicus—Ursus himself provides the rest by his confession.[174]

Kepler regards the problem as a matter of legal interpretation and eliminative argumentation. He represents his own reading of Copernicus as authoritative. No doubt, as a contemporary astronomer who was intimately familiar with *De revolutionibus*, his opinion on the controversy should give us pause. Yet, Kepler was also an interested party in the dispute even before Tycho requested of him an *apologia* against Ursus. For, in 1596, Kepler had penned a letter to the Imperial Astronomer in Prague (that is, Ursus), flattering him in no uncertain terms and seeking from him, in turn, approval of his recent work, *Mysterium cosmographicum*. Without the sort of prior approval that we moderns are accustomed to, Ursus had proceeded to publish Kepler's letter in full, in the following year, as a preamble to his violent attack on Tycho. Before too long, Kepler began to receive the repercussions of his action through Maestlin[175] and from Tycho himself. Thus, by 1599, as he was about to set out for Prague in search of Tycho's patronage, Kepler already had reason to look critically on Ursus.

Whatever his considerations, however, Kepler's interpretation of the evidence known to him was astute and seems to us largely correct. The passages cited by Ursus do not contain all the elements of Tycho's cosmology any more than they exhibit the principal features of Ursus' own

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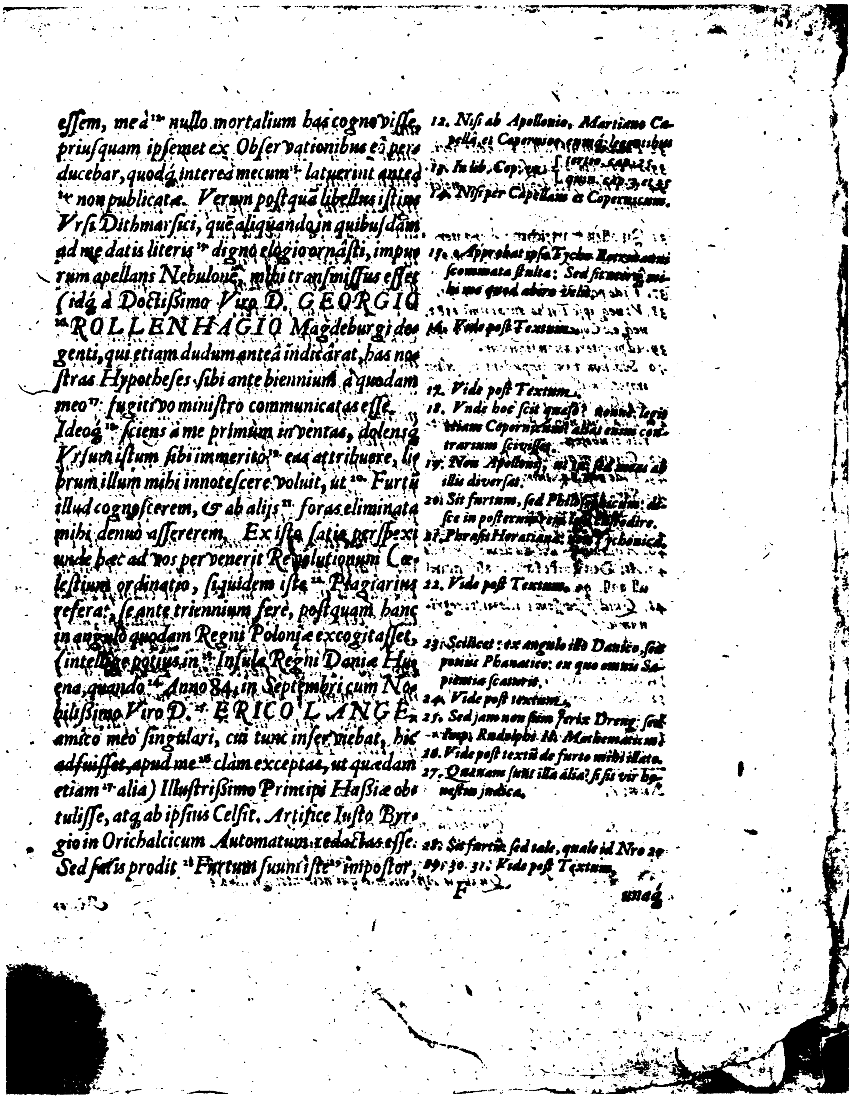
most clearly, and rests the main defence of his case on Copernicus, who expresses the matter less clearly, is such as to arouse great suspicion that Ursus never read Ptolemy, but rather that there was some other teacher who told Ursus that Apollonius' problem was reminiscent of something like the matter contained in Tycho's hypotheses. . . ." (Jardine, pp. 186–87). Later in the *Apologia*, Kepler drives home in a different way the impossibility of extracting Tycho's system from Copernicus' text. He distinguishes between a *body* of astronomical hypotheses that constitute "a definite conception of the form of the universe" and a single hypothesis concerned to account for a single phenomenon, such as planetary stations and retrogressions. If Apollonius shows us anything, he says, it is the latter.

[174] In side note 20 on sig. F1 of *De astronomicis hypothesibus*, Ursus writes, "Let it be a theft, but a philosophical one. Learn to safeguard your things hereafter." (See Figure 13.) Rosen, *Three Imperial Mathematicians* (supra n. 2), pp. 194–95, contends that this admission must be taken at face value, as Kepler apparently did. On the other hand, Ursus elsewhere (sig. Div) denies the theft, saying it "is a philosophical one, which I firmly deny having committed," and Jardine, *Birth of HPS*, pp. 31ff, convincingly argues that this is the standard rhetorical tactic of *confessio*, having the form "even if your claims are conceded, your case is not proven."

[175] Maestlin to Kepler, 4 July 1598, *Johannes Kepler Gesammelte Werke*, vol. 13, p. 236; quoted in Jardine, p. 12.



eſſem, meâ[11] nullo mortalium has cognoviſſe, priuſquam ipſemet ex Obſervationibus eâ perducebar, quodq́ intereà mecum[13] latuerint anteâ[14] non publicatæ. Verum poſtquā libellus iſtius Vrſi Dithmarſici, quē aliquando in quibuſdam ad me datis literis[15] digno elogio ornâſti, impurum apellans Nebulonē, mihi tranſmiſſus eſſet (idq́ à Doctiſſimo Viro D. GEORGIO [16] ROLLENHAGIO Magdeburgi degenti, qui etiam dudum anteâ indicârat, has noſtras Hypotheſes ſibi ante biennium à quodam meo[17] fugitivo miniſtro communicatas eſſe. Ideoq́[18] ſciens à me primum inventas, dolensq́ Vrſum iſtum ſibi immeritò[19] eas attribuere, librum illum mihi innoteſcere voluit, ut[20] Furtum illud cognoſcerem, & ab alijs[21] foras eliminata mihi denuò aſſererem. Ex iſto ſatis perſpexi unde hæc ad vos pervenerit Revolutionum Cœleſtium ordinatio, ſiquidem iſte[22] Plagiarius referat, ſe ante triennium ferè, poſtquam hanc in angulo quodam Regni Poloniæ excogitaſſet, (intellige potius in[23] Inſula Regni Daniæ Huena, quando[24] Anno 84. in Septembri cum Nobiliſſimo Viro D.[25] ERICO LANGE, amico meo ſingulari, cū tunc inſerviebat, hic adfuiſſet, apud me[26] clàm exceptas, ut quædam etiam[27] alia) Illuſtriſſimo Principi Haſſiæ obtuliſſe, atq; ab ipſius Celſit. Artifice Iuſto Byrgio in Orichalcicum Automatum redactas eſſe: Sed ſatis prodit[28] Furtum ſuum iſte[29] impoſtor,

12. Niſi ab Apollonio, Martiano Capellâ, et Copernico, eumq́ legentibus.
13. In lib. Cop. [illegible] {tertio. cap. [illegible] / quin. cap. 3. et 25
14. Niſi per Capellam & Copernicum.
15. Approbat ipſa Tycho. [illegible] ſcommata ſtulta: Sed ſit [illegible] mihi me quod [illegible] velit.
16. Vide poſt Textum.
17. Vide poſt Textum.
18. Vnde hoc ſcit quæſo? nonne legitimam Copernicanam aliàs etiam contrarium ſciviſſet.
19. Non Apollonij, ut [illegible] ab illis diverſat.
20. Sit furtum, ſed Philoſophicum: diſce in poſterum [illegible] cuſtodire.
21. Phraſis Horatiana: [illegible] Tychonica.
22. Vide poſt Textum.
23. Scilicet: ex angulo illo Danico, ſeu potius Phanatico: ex quo omnis Sapientia ſcaturit.
24. Vide poſt textum.
25. Sed jam non ſum ferix Dreng: ſed Imp. Rudolphi II. Mathematicus.
26. Vide poſt textū de furto mihi illato.
27. Quænam ſunt illa alia? ſi ſis vir honeſtus indica.
28. Sit furtū ſed tale, quale id Nro 20.
29. 30. 31. Vide poſt Textum.

F unaq́

Fig. 13. In side note 20, folio F, of Ursus' *De astronomicis hypothesibus* (1597), the author admits, for rhetorical purposes, to a "philosophical theft." (Collection of Owen Gingerich.)

scheme. Kepler pointed out in the *Apologia* exactly what was *missing* from the Apollonius passages in Copernicus and precisely what would be required in a full scheme. This passage is critical for our understanding of the difficulties faced by anyone then seeking to build a new cosmology from hints and suggestions in Copernicus' text: "He [Apollonius] leaves it open to astronomers whether they want to use a concentric with epicycle for all the five heavenly bodies which perform stations, or to use an eccentric for the three superior ones. And neither the reason for the disposition of the various orbs nor the comparison of their magnitudes is any concern of his."[176] In one respect, however, the Apollonius passage (III,25) is appropriate to its purpose: it alludes to the possibility of exchanging the earth and the sun while preserving intact the same predictive capacity. Beyond that, Copernicus offers no specific assistance on how such a transformation is possible. Nor does Apollonius of Perga. For Kepler, then, the conclusion is inescapable: Ursus has had help from someone else in reading the text of Copernicus and in providing something additional that has enabled him to conceive of a new hypothesis. And that person, of course, must be Tycho Brahe.

Or could it have been Paul Wittich? Next to the Copernican passage cited by Ursus, we find in Wittich's Prague copy (but in none of the other copies owned by him) his comment: "The hypothesis of the sun can be accommodated either to the earth's motion or to the sun's."[177] Taken alone, this succinct gloss on the passage in question gave no explicit means of further interpretation. Yet, at the back of the Vatican copy, Wittich showed exact methods for applying that proposition to each of the planets. All of this heightens the possibility that Wittich and Ursus had met at some point and that Ursus shared in the marginal wisdom of one or more of the Wittichian copies. Kepler's silence in the matter could be explained easily by the fact that he never laid eyes on any of the volumes. Nonetheless, a Wittich-Ursus connection would surely harmonize with Kepler's view that Ursus had found his scheme both in the Copernicus text and outside it.

These reflections carry us from texts to persons and their movements. Just how likely is it that Wittich and Ursus ever met? Here the information we have is complex and suggestive rather than absolutely conclusive. A detailed chronology of their comings and goings between 1584 and January 1586, the date of Wittich's death in Vienna, clarifies where the available evidence now stands:

- 1584 September. Ursus and Eric Lange visit Uraniborg for two weeks.[178]

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[176] Jardine, *Birth of HPS*, p. 192.

[177] Wittich's Prague *De revolutionibus*, f. 96.

[178] *Ibid.*, p. 24; Rosen, *Three Imperial Mathematicians* (supra n. 2), p. 13. A testimonial notarized at Cassel by a member of Eric Lange's retinue, Michael Walter, provides a detailed account of the alleged theft of Tycho's papers (see C. Frisch [ed.], *Joannis Kepleri astronomi opera omnia* [Frankfurt and Erlangen, 1858–1871], I, pp. 230–31). For a translation of this account see Rosen, pp. 250–53.

- 1584 September-October. Early in October Dudith has heard that Wittich attended the Frankfurt Book Fair.[179] Later Dudith reports from Breslau that Wittich has been away from that city "for several months."[180]
- 1584 November 7. Wittich observes an eclipse at Cassel with Rothmann.[181] According to Ursus, in this year Wittich brought the prosthaphaeresis method to Cassel.[182]
- 1585 October. Ursus himself claims to have thought up his world system in Pomerania[183] although Tycho expresses doubt that Ursus was ever "in a certain corner of Poland."[184]
- 1585 October 20. Landgrave Wilhelm refers to instruction by Wittich that has allowed him to improve his instruments, but he does not mention either Wittich's arrival or any departure.[185]
- 1585 Autumn. "A certain runaway assistant" of Tycho's (Ursus?) is reported to have imparted a cosmology, presumably Ursus' geoheliocentric version, to George Rollenhagen at Magdeburg.[186]
- 1586 January 9. Wittich dies in Vienna.[187]
- 1586 May. Ursus reveals his cosmology at Cassel.[188]
- 1587 September 21. Rothmann writes to Tycho that Wittich has died.[189]

Several conclusions emerge from our chronology. First, no independent testimony exists for Ursus' claimed date of discovery. However, since the date occurs *after* the visit to Hven in 1584, there are some grounds for accepting it. Had Ursus wished to cover himself completely, he would have produced a discovery date *prior* to the meeting with Tycho. Second, we do not know where Ursus was for the eleven months between September 1584 and October 1585; during this time, he could conceivably have met Wittich. Third, we do not know exactly when Wittich left Cassel. Did he go directly from Cassel to Vienna late in 1585? Fourth, we do not know precisely when Ursus arrived in Cassel, although certainly no later than May 1586.

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[179] Dudith to Praetorius, 9 October 1584, Wroclaw University Library MS 1949/594, Rhedigeriana LXVI.

[180] Dudith to Praetorius, 12 December 1584, Wroclaw University Library MS 1949/594, f. 39v = Rhedigeriana LXIV.

[181] Rothmann to Brahe, 21 September 1587, *TBOO,* VI, 116:17–18.

[182] Ursus, *De astronomicis hypothesibus,* sig. I3.

[183] *Ibid.,* sig. Aij.

[184] Brahe to Rantzau, 21 December 1588, *TBOO,* VII, 388:19-20; translated in Rosen, *Three Imperial Mathematicians* (supra n. 2), p. 40.

[185] *TBOO,* VI, 31–32.

[186] Rollenhagen to Rantzau, letter no longer extant but mentioned in Brahe to Rantzau, *TBOO,* VII, 388–89, translated by Rosen, *Three Imperial Mathematicians,* pp. 43–44; it is also referred to by Tycho in his letter to Peucer of 13 September 1588, *TBOO,* VII, 135:38–42; translated by Rosen, p. 24. In a footnote to the Peucer letter, Dreyer (*TBOO,* VII, 408) identifies the "runaway assistant" as Ursus, but Tycho, in the Rantzau letter, is not at all sure and inquires further.

[187] Henel, *Silesia togata* (see n. 66). This is confirmed by a letter from Dudith to Praetorius, 10 October 1588: ". . . in Vienna where he contracted fever from a chill and died of phrenesis (as they call it) well over two years ago." (Esztergom, p. 71: ". . . itaque interim erant Viennae, ubi mortuus est ex phrenesi (ut aiunt) ante biennium & amplius, febrem ex frigore contraxerat." According to A. Cornelius Celsus, *De medicina libri octo* (Lyon, 1665) (2.1 and 3.18), phrenesis is a dementia arising from an inflammation of the brain. We thank Lech Szczucki for assistance in reading this letter.

[188] Ursus, *De astronomicis hypothesibus,* sig. Aij.

[189] *TBOO,* VI, 117:2. Wittich is not mentioned by name here, but the context is clear; see Dreyer's endnote, p. 356.

Yet some communication between Wittich and Ursus could conceivably have occurred. If we take the Landgrave's reference to Wittich as evidence that Wittich was still in Cassel in October 1585, and if Ursus arrived at Cassel before January, then they could have met in the late fall of 1585, although the time interval seems so narrow as to make such a meeting uncertain. In any event, Ursus could well have learned about Wittich's cosmological ideas from the astronomers at Cassel, just as he admitted learning about the trigonometrical prosthaphaeresis methods there. After Wittich's untimely death in January, then, Ursus would have been free to incorporate Wittich's insights into a new cosmology, to adjust the date of his discovery, and to credit Wittich with discoveries about the prosthaphaeresis method. Kepler's informed guess that Ursus had made a textual discovery with someone's help agrees well with the possibility that Ursus had somewhere encountered Wittich or had come into contact with his ideas in the Cassel community. And it is also consistent with what must otherwise seem an odd stratagem: Ursus' charge that Tycho had derived his system from Copernicus; for such a charge may well reflect Ursus' own route to a new world system, an arrangement of the planets closer to Wittich's than to Tycho's. Quite possibly Ursus has inadvertently told us more about himself than about Tycho.

IIIC. Constructing Tycho's Cosmology

When Wittich left Hven in October 1580, he took with him his books but he left his noble host with much to ponder, and especially about the planet Mars. To begin with, Tycho and probably Wittich himself must have realized that Mars' parameters conflicted with the picture that Wittich had drawn on the last page of his Vatican notes. Thus, Wittich's visit must have piqued Tycho's interest in Mars, and at the same time, the new instruments under construction (including the famous mural quadrant) gave Tycho the opportunity to launch an attack on the ruddy planet.[190] In the winter of 1582-83, at the northernmost opposition of Mars, Tycho began a vigorous observational campaign.

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[190] Victor Thoren, "New Light on Tycho's Instruments," *Journal for the History of Astronomy*, 4 (1973), 25–45.

Tycho knew that there was as yet no viable observational test to decide between the Copernican and Ptolemaic arrangements. However, he also realized that a measurement of the Martian distance at opposition could distinguish between the two, because in the Ptolemaic scheme Mars always lay beyond the sun, whereas in the Copernican system Mars would regularly approach to less than the sun's distance. By measuring the positions of Mars both in the evening and in the morning, Tycho had a baseline equal to a chord through the earth at his latitude, roughly an earth's radius. He supposed that the sun had a parallax of 3′, so if Mars came closer than the sun he should have been able to work with an angle in excess of 3′, just within his observational limits. He used several instruments to make such observations on the night of 26-27 December 1582, and again on a few occasions in January—far from an exhaustive campaign for a most subtle phenomenon. In fact, the sun is twenty times more distant than Tycho assumed, and the most favorable possible morning-evening parallactic angle for Mars would have been half a minute of arc, below naked-eye resolution. At any rate, as late as 1584 he knew that his quest was extremely difficult, for he reported that he had found no significant parallax.[191]

The crucial point is that by casting the rearrangement of the heavens into an observational problem, Tycho had defined the question in terms of his own special competence and authority. He recognized that the Ptolemaic system, satisfying as it was with respect to the terrestrial physics of an immobile earth, did not take into account the ubiquitous annual motions in the epicycles, shown so clearly in Wittich's final Vatican drawing. If he wished to take advantage of the systematic heliocentric linkages or to preserve them in a fixed-earth variant thereof, he needed to establish a large parallax for Mars. In order to advance his reputation as the restorer of astronomy, it was very much in his interest to be the purveyor of a new cosmology, and as the lord of castle Uraniborg, built "for the contemplation of philosophy, especially the stars,"[192] it behooved him to find a large parallax for Mars.

By 1587, Tycho had changed his mind about what he had actually found at the 1582-83 opposition. To the Landgrave Wilhelm, he wrote:

> With respect to the planet Mars, at the end of the previous and beginning of the same year when it was in opposition and high up in the latitude of Cancer, the highest in the north it ever gets, I ventured to investigate whether its parallax was larger than the sun's, which would be necessary for the Copernican hypothesis to hold true. Now through this, Mars in opposition to the sun comes out about

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[191] Brahe to Brucaeus, 1584, *TBOO*, VII, 80:8–16.

[192] From the cornerstone of Uraniborg, *TBOO*, IV, 143; quoted by Owen Hannaway, "Laboratory Design and the Aim of Science: Andreas Libavius versus Tycho Brahe," *Isis*, 77 (1986), 585–610.

> a third part nearer the earth than the sun itself. Thus, also from this, necessarily follows a larger parallax, and as a consequence, Mars' orbs of revolution do not always lie beyond the solar orb, as the Ptolemaic hypotheses require. Hence either the earth is carried around by an annual motion, by which all the epicycles of the planets are dismissed; or there must be sought another arrangement of the celestial revolutions than has hitherto been made. Actually, these things lie outside our present purpose, but God willing, something clearer and more detailed will be forthcoming.[193]

Eighteen months later, after the long-drawn-out printing of *Concerning Recent Phenomena in the World of Aether* had come to an end, Tycho made his reasoning somewhat more explicit: in a letter to Caspar Peucer he stated that Mars was nearer the sun because it retrograded faster than it should according to the Alfonsine Tables.[194] In communications to Rothmann and to Hagecius he simply declared that his careful observations showed that Mars must come nearer than the sun.[195] These letters echoed the stark claims in his book that the new cosmology "corresponded most aptly with all the celestial appearances" and that "no absurdity follows from this arrangement of the heavenly orbs because Mars at opposition is nearer the earth than the sun itself."[196]

Ironically, Brahe claimed triumph in his warfare on Mars despite the fact that, unknown to him, he had taken up a task that was insoluble by naked-eye astronomy. Kepler was later to look in vain for the critical observations, and eventually thought he had found the explanation: in his *Astronomia nova* Kepler exclaimed, "But behold an unexpected thing!"[197] Tycho's assistants, instead of computing the baseline from the earth for establishing the triangulation, had actually made an elaborate Copernican calculation and had necessarily found that at opposition Mars is closer than the sun. "Thus Brahe had intended one thing but his students carried out another," wrote Kepler. "Whether it was just from trust in his assistants that Brahe made his pronouncement about the parallax, I do not know." Kepler's solution was not the last word, however, for in 1913, J.L.E. Dreyer discovered a closely related manuscript for investigating the parallax, but this time in Tycho's own hand.[198] According to what Tycho had written to Peucer, he had eventually attempted to use the speed of the daily retrograde motion of Mars to determine its relative distance. Tycho had deluded himself, of course, as may be plainly seen in noticing that the Ptolemaic arrangement predicts the same daily angular velocities while keeping the planet forever beyond the sun.

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[193] Brahe to Landgrave Wilhelm, 18 January 1587, *TBOO*, VI, 70:29–42.

[194] Brahe to Peucer, 13 September 1588, *TBOO*, VII, 129:20–26 and note also 136:25–27.

[195] Brahe to Rothmann, 21 February 1589, *TBOO*, VI, 179:3; Brahe to Hagecius, 1 November 1589 Old Style, *TBOO*, VII, 199:17–23.

[196] *TBOO*, IV, 158–59.

[197] *Johannes Kepler Gesammelte Werke*, vol. 3, 121:18ff.

[198] Owen Gingerich, "Dreyer and Tycho's World System," *Sky and Telescope*, 64 (1982), 138–40.

Our problem thus narrows to the question of why Tycho believed, or at least reported his belief, that he had deduced a parallax that could not, in fact, be measured with his grand instruments. By the winter of 1587, Tycho's fears and suspicions came to a head. He suspected that Wittich was divulging all sorts of secrets at Cassel as well as teaching a cosmology of his own. He was also worried that Ursus had stolen a version of it from Hven. Together these factors may have spurred Tycho to consider more intensely his own cosmology and to confront the nexus of problems that Mars presented: the interpenetration of the spheres and the nature of celestial matter.

Few questions have vexed historians of astronomy as much as the nature of the celestial spheres.[199] Lying at the crossroads between mathematical astronomy and natural philosophy, the problem of celestial matter was a microcosm of the more general relation between those disciplines. In recent years, we have come to realize that the radical Aristotelian separation of heavens and earth into absolutely distinct realms, a distinction that was canonized in the work of Thomas Aquinas, had begun slowly, although not uniformly, to give way in the sixteenth century. As Charles Schmitt has shown, Aristotelianism was no monolithic corpus; Aristotle appeared in many different guises to the sixteenth-century reader.[200] And William Donahue has called attention to several factors implicated in a changed view of the heavens:[201] (1) a growing independence from ancient authority; (2) the emergence of previously ignored Stoic doctrines of a single continuum of matter; (3) the rise of Scriptural literalism and, with it, new attention to passages in the Bible that contradicted Aristotle's account of the heavens[202]; and (4) the "nature philosophies" of such figures as Cardano, Paracelsus, Telesio, Bruno and Campanella.

Tycho Brahe was not untouched by these developments. He was often critical of Aristotle's natural philosophy. He was impressed by the writings of Paracelsus and Cardano, among others. He knew the optical claims of the Royal Professor of Mathematics at Paris, Jean Pena, that the heavens consist of air.[203] He accepted Philipp Melanchthon's strong views on astrological influence and followed his moderate skepticism as a guide to what was knowable. But, perhaps most important of all, it was Tycho who shifted the discourse of the spheres' existence from natural philosophy into the mathematical part of astronomy.[204]

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[199] See, in particular, Noel M. Swerdlow, "Pseudodoxia Copernicana: or, enquiries into very many received tenants and commonly presumed truths, mostly concerning spheres," *Archives Internationales d'Histoire des Sciences*, 26 (1976), 108–58; Nicholas Jardine, "The Significance of the Copernicus Orbs," *Journal for the History of Astronomy*, 13 (1982), 168–94; Westman, "The Astronomer's Role" (supra n. 2), pp. 113–16; Eric Aiton, "Celestial Spheres and Circles," *History of Science*, 19 (1981), 75–113; William H. Donahue, "The Solid Planetary Spheres in Post-Copernican Natural Philosophy," pp. 244–75 in Robert S. Westman (ed.), *The Copernican Achievement* (Berkeley and Los Angeles, 1975); Edward Rosen, "The Dissolution of the Celestial Spheres," *Journal of the History of Ideas*, 45 (1985), 13–31; Edward Grant, "Celestial Orbs in the Latin Middle Ages," *Isis*, 78 (1987), 153–73.

[200] *Aristotle and the Renaissance* (Cambridge, Mass., 1983).

[201] "The Solid Planetary Spheres," in Westman (ed.), *The Copernican Achievement*, pp. 247–48 (supra n. 199).

[202] Tycho, for example, quotes Isaiah 40:22 to Peucer ("he stretcheth out the heavens like a curtain and spreadeth them out as a tent to dwell in") to refute the pagan notion of solid spheres, 13 September 1588, *TBOO*, VII, 133:28ff.

Many of these themes appear in his important *Vonn der Cometten Uhrsprung* of 1578, where he entertained the question of the comet's substance.[205] "The opinion of Aristotle is entirely false," he wrote, "when he asserts that comets are drawn upwards from the earth into the air and that they cannot be generated in the heavens, for he has established this on the basis of his own good thoughts and not from any mathematical observation or demonstration." Against Aristotle, Tycho then brought forth the opinion of the Paracelsians as a modern counter-authority:

> The Paracelsians hold and recognize the heavens to be the fourth element of fire, in which generation and corruption may also occur, and thus it is not impossible, according to their philosophy, for comets to be born in the heavens, just as occasional fabulous excrescences are sometimes found in the earth and in metals, and monsters among animals. For Paracelsus is of the opinion that the Superior Penates, which have their abode in the heavens and stars, at certain times ordained by God, fabricate such new stars and comets out of the plentiful celestial matter and display them clearly before mankind as a sign of future things which do not have their true origin in the planets but are rather caused and augured in opposition to the planets by the Pseudoplanet, as a comet is called.[206]

In this revealing passage, Tycho uses the views of the Paracelsians to open the possibility that comets are "occasional fabulous excrescences," heavenly freaks akin to earthly monsters. But he does not then draw the conclusion that celestial matter is *universally* alterable. Comets are "miraculous portents" that are *somehow* created in the heavens; the heavens themselves, however, "are composed of the most subtle, most translucent and imperishable of all materials." How, then, are comets made? Does God Himself make them from nothing? Or, are they constructed from the already existing heavenly matter by some intermediate powers, such as Paracelsus' Superior Penates? In a truly Melanchthonian spirit, Tycho urges philosophers to adopt a posture of "modest ignorance" (*ignorantia modeste*) and to say "that comets are a special creation of God that come from unknown natural causes, of which we do not know how they are born."

Now, if alterability is, in effect, an *occasional* property of celestial matter, then it would not apply to the normal, immutable state of the heavenly spheres. And this distinction helps to make sense of Tycho's general view, expressed in a letter to Caspar Peucer in 1588, that "I was still imbued with the opinion, accepted for a long time and approved by almost everybody, that Heaven is crammed full of certain real orbs carrying the stars."[207] The Tycho who could write of his adherence to such "real orbs" did not change his views about their existence merely on the grounds of Paracelsian authority, although his acquaintance with Danish Paracelsians, notably Petrus Severinus and Johannes Pratensis, could have planted in his mind the possibility that the heavens were generally mutable.

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[203] Peter Barker, "Jean Pena (1528-58) and Stoic Physics in the Sixteenth Century," *The Southern Journal of Philosophy*, 23 (1985), 93–107, especially p. 101.

[204] See Westman, "The Astronomer's Role" (supra n. 2), pp. 122–26.

[205] We rely here on the English translation of this work by John Christianson, "Tycho Brahe's German Treatise" (supra n. 136), pp. 132–40; where helpful, we provide references to the original in *TBOO,* IV, 381–96.

[206] *Ibid.*, 133. All references are to this page.

At the heart of Tycho's "instauration of astronomy" was, however, a conviction in the precise measurability of the visible world. Landgrave Wilhelm's rival group of astronomers and technicians at Cassel, as well as the academics concerned with parallax methods, shared this same ideal. It makes sense, then, to look as well at Tycho's measurement determinations for the source of his views on the spheres. Victor Thoren and Edward Rosen have pointed to the influence on Tycho of two significant, mathematical astronomers in forcing a decisive turn in the dissolution of the spheres. Thoren has suggested the importance of Michael Maestlin's study of the Comet of 1577. Maestlin's figures showed the comet's distance varying from 155 to 1495 earth radii, the latter distance plunging the bearded object through the Ptolemaic sphere of Venus.[208] And, in the last article written before his death, Rosen built on Bruce Moran's discovery that it was Christoph Rothmann who made the critical break with the tradition of solid spheres.[209] In chapter V of his *Descriptio accurata cometae anni 1585*, Rothmann wrote:

> Most philosophers heretofore have stated, and it is commonly believed, that the planetary spheres are solidly compact bodies, which by their own motion securely transport the planets attached to them. . . . The solid bodies permit no penetration of their region. . . . This belief in celestial spheres is promulgated by the greatest writers, and commonly possesses the authority of a general axiom. Nevertheless, [impelled] by my love of truth, I shall prove that it is absolutely false. . . . I shall also show that between the sphere of the fixed stars and the earth there is nothing but this airy element, and that the seven planets are suspended only in the air. . . . The planetary spheres are nothing but air, and they are marked off not in reality but only by reason, and are assigned to the planets so that each does not transgress the space allotted to it. . . . Thus it is now clear how a comet can be or move in the sphere of Saturn. . . . The very motion of the comets is the strongest argument that the planetary spheres cannot be solid bodies. For it cannot happen that a solid body permits a penetration of its region. So you cannot pass with your body

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[207] Brahe to Peucer, 13 September 1588, *TBOO*, VII, 130:9–11.

[208] Thoren, "The Comet of 1577" (supra n. 2), p. 61.

[209] Bruce Moran, "Christoph Rothmann" (supra n. 34), 103ff; Rosen, "The Dissolution of the Solid Celestial Spheres" (supra n. 199), 26–31. As usual Rosen attacks minor typographical errors in Moran's article while failing to credit its major contribution.

through a wall. For, two bodies cannot be in the same physical space at the same time.[210]

Tycho received a copy of Rothmann's treatise and "read it through again and again" and "was wonderfully pleased."[211] To Rothmann he now wrote: "I would readily agree with you, as you assert in the part you sent me, that the heaven is all air and does not consist of solid matter; it is, indeed, nothing but air." But then he added, more vaguely: "Truly, many years ago I was *not* of the opinion that any orbs really exist in heaven, and that the heavenly material is hard and impenetrable."[212] Rothmann's reply mirrored Tycho's position: "You correctly agree with me that the celestial spheres' matter is not hard or impenetrable, but fluid and fine, easily yielding to the planets' motion."[213] Four years later in 1591, at the request of King Frederick II, Tycho produced a short vernacular work at his own press. To the work written by his assistant Peter Jacobsen Flemløse, Tycho added a brief preface in which he described the regions of heaven and earth as filled with air.[214] It was his final attempt to draw together the heavenly and earthly realms into a single philosophy of nature.

Precisely when and why Tycho decided to allow the interpenetration of the orbs may never be known. Although he referred obliquely to 1583 as the date when he allegedly discovered his world system,[215] the evidence just cited would seem to suggest that he formed a genuine conviction only as late as January 1587.[216] By then, as we have seen, his honor within the community of Hapsburg mathematical practitioners was at stake. To summarize: he believed Ursus and Wittich to be laying claim to new world pictures that were, except for the interpenetration of Mars' and the Sun's orb, closely identical to his own. His instrumental and calculational secrets had been spilled for all to see at Cassel. Now Rothmann, the Landgrave's own astronomer, was preparing to reject the very existence of the spheres in public. The much-heralded parallax measurements boiled down to guesswork. In the face of these considerations, Tycho asserted noble prerogative. He shoved his geoheliocentric sketch into a grand cometary treatise; he proclaimed an end to the celestial orbs and displayed the intersection of the orbits of Mars and the Sun. None of the principals—

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[210] Sent to Brahe in manuscript, later published by Willebrord Snel in *Descriptio cometae qui anno 1618 . . . effulsit* (Leiden, 1619), cited and translated by Rosen, *ibid.*, pp. 28–29.

[211] Brahe to Rothmann, 20 January 1587, *TBOO,* VI, 85:30-34; Rosen, *ibid.*, p. 27.

[212] *TBOO,* VI, 88:2–7.

[213] *Ibid.*, 111:24–26.

[214] John Christianson, p. 316:6–11 in "Tycho Brahe's Cosmology from the *Astrologia* of 1591," *Isis,* 59 (1968), 312–18.

[215] In *De mundi* (*TBOO,* IV, 155:40) Tycho writes that he had conceived his system "more than 4 years ago." Dreyer (*Tycho Brahe,* p. 167) points out that *De mundi* "was written in 1587, as appears from several allusions to time in it." In his *Astronomiae instauratae mechanica* of 1598 (*TBOO,* V, 115:10), Tycho says he found his hypothesis "more than 14 years ago." See n. 70.

[216] The later date is favored by Thoren and Rosen, although for different reasons.

neither Rothmann nor Wittich nor Ursus nor Maestlin—received any notice in the cosmological chapter.

We have now seen that there was nothing at all internally self-evident or obvious about Tycho's cosmology. Tycho secured his world system by invoking a rhetoric of observation, but since he never provided any detailed measurements, only his noble authority sustained its credibility. The major thrust of Tycho's writings deal with celestial distances, and he established himself as the pre-eminent authority on the *lack* of measurable parallaxes for the Nova of 1572 and the Comet of 1577—but for Mars he was compelled to believe what his observations could not have revealed, a measurable parallax. Wittich's shadowy presence in the story helps us to understand how pressures for cosmological reform were building in the 1570s and '80s. His planetary diagrams, of which Tycho seems fully aware—even if reluctant to mention their existence—must have been a catalyst in the Lord of Knudstrup's own thinking. When Tycho hinted to the Landgrave that, God willing, a clearer and more detailed alternative might be forthcoming, he was probably looking nervously over his shoulder as much to Wittich as to Ursus, for he did not yet know that Wittich had died.

The marginalia in Wittich's copies of *De revolutionibus* provide an invaluable documentary record, in a depth and detail previously missing, of how Copernicus' book was actually being studied. In the late 1570s and early 1580s, it was Wittich who engendered the communal discussion of this text. The Wittich connection helps us to understand what are otherwise puzzling aspects of late-sixteenth-century cosmology: the multiple appearance of geoheliocentric systems, Tycho's shift toward the problem of the ordering of the planets after 1580, the search for a justification of the spheres' intersection.

In the end, Wittich did not live to see the "restoration of astronomy." It was only the clownish Bear who staggered onto the field, for which he earned disproportionate rage. Tycho called him "rotten and sycophantic," filled with "excessive arrogance, buffoonery and shameless lying," and a "crow of Aesop, adorning himself in the plumes of others."[217] Indeed, had Wittich lived, he could well have shared Tycho's wrath; and it may have been a benevolent irony that Wittich perished *before* he published.

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[217] Brahe to Clavius, 5 January 1600, (supra n. 63), p. 377:27; Brahe to Jessenius, 28 March 1600, *TBOO*, VIII, 281:37–38, translated by Rosen, *Three Imperial Mathematicians*, p. 259.

Appendix I
The Vatican Annotations

Note: In these transcriptions we place many of the capitalized words into lower case. In general, we follow the punctuation as given, recognizing that the period, for example, often plays a role closer to a comma in modern English, an understanding that is reflected in the translations. We complete, without comment, abbreviations explicitly indicated, whereas we provide square brackets for implicit abbreviations. Transcribed text is in italics, translations are in roman, and our comments are in slanted type.

Introduction: Wittich's planetary diagrams at the back of the Vatican De revolutionibus take as their point of departure a commentary found at the back of the Liège De revolutionibus. The Liège document is in the hand of an unidentified earlier annotator who faithfully copied many of Erasmus Reinhold's notes, including several pages of additional material at the end of the Wittenberg professor's volume. While this commentary is situated among the other Reinholdian addenda copied into the Liège volume, it is not now present in Reinhold's De revolutionibus (at the Royal Observatory, Edinburgh), but it is definitely within the spirit of Reinhold's other work and quite possibly part of his corpus.

The Liège commentary constitutes a clarification of the chapter by Copernicus entitled, "By what ways the planets' own motions appear nonuniform" (V,4). Copernicus describes two alternative arrangements, the first called an "eccentrepicycle" and the second an "epicyclepicycle" or double epicycle, and Reinhold in his copy carefully labels these *I. Primus modus per Eccentrepicyclum* and *II. Secundus modus per homocentrepicyclos*. Copernicus further mentions, in a clause, "even by some of the other aforementioned modes"; Reinhold repunctuates the sentence to make this phrase stand alone, and in the margin writes *III. De reliquus modis*. By including a third, non-specified mode, Reinhold makes the arrangements for the planets comparable to the trimodal solar theory in Book III, chapter 20, where Copernicus remarks that "I cannot easily say which [of the three] is right except that the continual agreement of the computations and appearances forces us to believe that it is one of them." The modes for the solar theory and for the planetary theory are parallel, but the numbering is not. The eccentreccentric arrangement that Copernicus described first for the sun is here relegated to the vague phrase *per quemlibet aliorum modorum*, where it becomes Reinhold's third mode for the planets; in contrast, the third solar mode becomes the mode of choice for the planets. In any event, the Liège commentary stops short of describing the third mode, which is where Wittich begins on Vatican f. 197v.

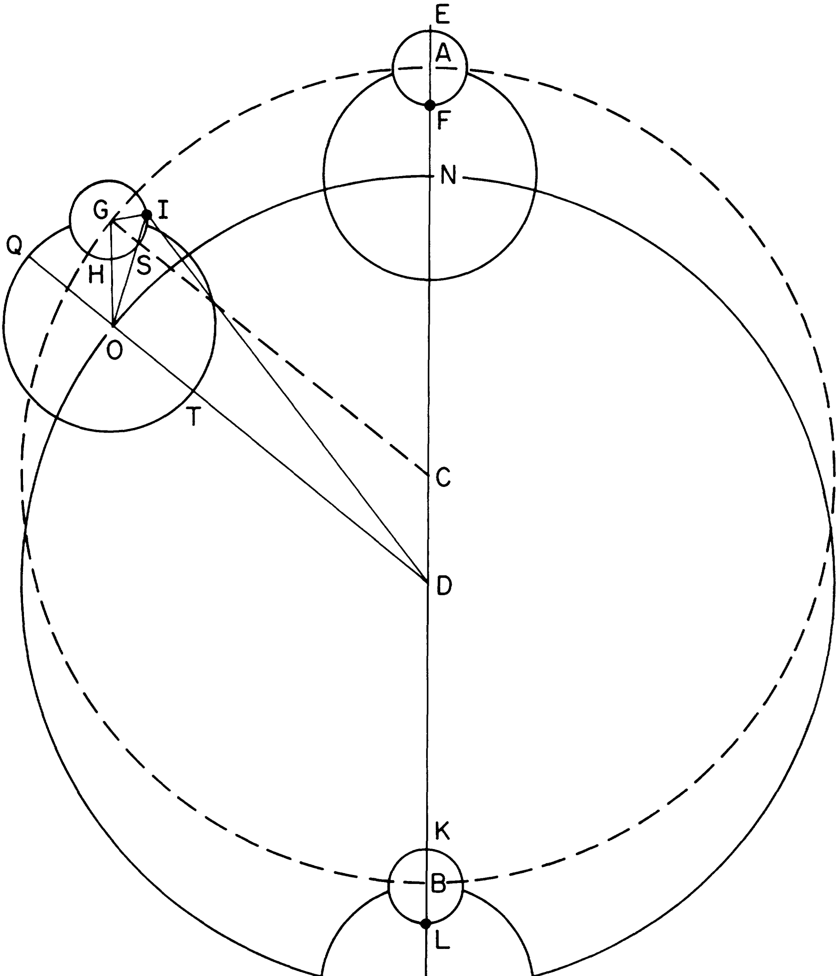


Fig. 14. The first and second modes for the superior planets, redrawn from Liège f. 203v.

We begin with a transcription of the Liège commentary to provide an introduction to the Copernican techniques. A derivative copy of this text is also found in the Wolfenbüttel De revolutionibus, *Herzog August Bibliothek, 21.1 Astron, ff. 203v–204v.*

[Liège, f. 203v]

In tribus superiorib[us] recenset Copernicus duos modos, seu duplex genus hypothesium juxta quorum utrumque eadem contingunt.

PRIMUS MODUS [preceding words in red] *habet eccentricum, qui defert epicyclum ὁμοταχές, ita ut dum centrum ἐπικ[ύκλου] tenet ἀπογείον seu summam absidem ecc[entrici], planeta sit in epicyclo περιγειότατος, moveaturque in una parte epicycli in praecedentia, in suprema autem in consequentia. Postremo epi[cycli] semidiameter sit triens eccentro[te]tis, ut in praecedenti schemate sit eccentricus in consequentia AGB centro C. Centrum autem universi D summa absis A, infima B. Dum centrum epicycli in A, epicyclum ipsum sit EF, & locus planetae in F [inserted above the line, in red: perigeo epicycli]. Dum vero centrum epi[cycli] in B, epicyclium quidem KL, & locus [f. 204] planetae in L [inserted above the line, in red: apogeo epicycli]. Perigeon autem & apogeon epi[cycli] semper existat in linea, quae per centrum eccentrici & epicyclii producitur.*

Copernicus considers two modes for the superior planets, or rather two kinds of hypotheses according to both of which the same things take place.

The FIRST MODE has an eccentric that carries an epicycle of the same speed, such that when the center of the epicycle is at the apogee or farthest apsis of the eccentric, let the planet be in the epicycle closest to the earth and move in precedence *[clockwise]* in that part of the epicycle, but in consequence *[counterclockwise]* in the farthest part. Finally, let the radius of the epicycle be one-third of the eccentricity, and as in the preceding diagram *[reproduced here]* let the eccentric AGB [move] in consequence *[counterclockwise]* about center C. The center of the universe is at D and has its farthest apsis at A and its nearest at B. When the center of the epicycle is in A, let the epicycle itself be EF and the place of the planet be at F, the perigee of the epicycle. When the center of the epicycle is in B, however, let the epicyclet be KL and let the place of the planet be in L, the apogee of the epicycle. But let the perigee and apogee of the epicycle always lie on the line produced through the center of the eccentric and epicyclet.

Commentary: *The first mode consists solely of the dashed eccentric circle about C and the small epicyclet whose radius is 1/3 of the eccentricity CD; the mean sun is at D. This is the eccentrepicycle mode that*

[Liège, f. 204]

SECUNDUS MODUS [preceding words in red]. Habet homocentrum aequalem eccentrico magnitudine & velocitate, qui defert geminum ἐπικυκλὸν, quorum primi semidiameter est aequalis eccentroteti, et centrum eius defertur ab homocentro in consequentia. Secundi autem epicyclii semidiameter triens est eccentrotetis, & centrum eius circumfertur à primo epicyclo in superiori parte in praecedentia. Movetur autem planeta in hoc secundo epicyclio, & in ima eius parte in praecedentia. Postremo & homocentricus & maior epicyclus sunt ὁμοταχεῖς. Secundum autem seu minus ἐπικύκλιον sit duplo velocius utroque, id est homocentrico & primo epicyclo, hac lege, ut dum centrum epi[cycli] fuerit in summa abside eccentrici prioris, centrum secundi epicycli sit item in apogeo primi epicycli, planeta vero in perigeo sui epicyclii, scilicet secundi, à quo immediate circumvehitur. Ut sit homocentricus NOP et dum N centrum primi epicycli sub apogeo eccentrici, F, locus planetae in epicyclii perigeo. Dum vero B centrum primi epicycli sub perigeo eccentrici, L, locus planetae item in epicyclii perigeo. Perigeon autem & apogeon epicyclii semper est in linea, quae per utriusque epicycli centrum agitur. [In a later hand and not present in the Wolfenbüttel copy:] Ergo in medio transitu erit in auge.

The SECOND MODE has a homocentric equal in size and speed to the eccentric, which carries a double epicycle in which the radius of the first is equal to the eccentricity, and its center is carried by the homocentric in consequence *[counterclockwise]*. Now the radius of the second epicyclet is a third of the eccentricity, and its center is carried around by the first epicycle in precedence *[clockwise]* in the upper part. However, the planet is moved in this second epicyclet and in its lowest part in precedence *[clockwise]*. Further, both the homocentric and the larger epicycle have the same speed. Now let the second or smaller epicycle be twice as fast as the homocentric and the first epicycle by this rule, that when the center of the epicycle is in the farthest apsis of the previous eccentric *[referring to the first mode]*, the center of the second epicycle is likewise in the apogee of the first epicycle, but the planet is in the perigee of its epicyclet (namely, the second *[or smaller epicycle]*), by which it is directly carried around. Now let the homocentric be NOP, and when N, the center of the first epicycle, is under the apogee of the eccentric [A], F, the planet's place, is in the epicyclet's perigee. But when the center of the first epicycle P *[despite B in the text]* is under the perigee of the eccentric, L, the planet's place, is similarly in the perigee of the epicyclet *[that is, closest to the center of the larger epicycle]*. Now the perigee and apogee of the epicyclet are always in the line that passes through the center of both epicycles. Therefore, at mean passage *[i.e., 90° from the apsidal line]* [the planet] will be in the apogee [of the epicyclet].

ΣΎΓΚΡΑΣΙΣ [preceding word in red]. Quod autem iuxta utrumque modum eadem contingent breviter ostendi potest. Primum enim manifestum est epicyclum in utroque modorum esse eiusdem magnitudinis, sicut eccentricus et homocentricus aequales circuli. Estoque iuxta viam eccentrici centrum epicyclii in G, et agatur ex D semidiameter homocentrici, parallela ipsi CG. Erit igitur iuxta hypothesin aequalitatis motuum, ob aequalitatem angulorum ACG et ADO, centrum maioris epicycli quod ab homocentrico circumfertur in O, eritque per hypothesin & 34 primi Elementorum connexa GO recta, aequalis & parallela ipsi CD. Centro igitur O intervallo autem eccentricitatis CD descriptus epicyclus QT transibit per signum G. Et quoniam GO parallela est ipsi CD, aequalis est angulus QOG angulo ADO. Quare iuxta hypothesin erit centrum secundi epicyclii in G dum centrum primi in O. Atque hic etiam locus erit centri epicycli iuxta viam eccentrici. Nunc si sumamus iuxta viam eccentrici locum planetae in epicyclio in signo I, hoc est, angulum SGI aequalem angulo ACG, planeta eiusdem sarcietur locum I iuxta viam homocentrici, quod quidem manifestum erit, iuxta hypotheses, si constabit angulum HGI duplum esse anguli ADO. Cum autem angulus SGI sit aequalis angulo ACG hoc est ADO. Angulus vero SGH aequalis item angulo eidem ADO. Quare eidem angulo ADO, aequalis est uterque angulus IGS et SGH. Ambo igitur, hoc est, totus angulus IGH duplus est anguli ADO, etc.

COMPARISON. That the same things take place according to both modes can be briefly shown, for it is clear that the first epicycle has the same size in both modes just as the eccentric and homocentric have equal circles. And according to the eccentric *[first]* mode, let the center of the epicyclet be at G and let the radius of the homocentric be drawn from D parallel to CG. Therefore according to the hypothesis of the equality of motions, on account of the equality of the angles ACG and ADO, the center of the larger epicycle that is carried around by the homocentric will be in O, and both by the hypothesis and by *[Euclid's] Elements* I,34 the line connecting GO will be equal and parallel to CD. Therefore, the epicycle QT described with the center O and the radius set equal to the eccentricity CD will pass through the letter G. And since GO is parallel to CD, angle QOG is equal to angle ADO. Therefore according to the hypothesis the center of the second epicyclet will be at G when the center of the first is at O. And this will also be the place of the epicycle's center according to the eccentric mode. Now if we assume that the planet's place in the epicyclet according to the eccentric mode is at the letter I, that is, angle SGI equals angle ACG, the planet will also come into its place I according to the homocentric *[second]* mode, which indeed will be clear, according to the hypotheses, if it is established that angle HGI is twice angle ADO. But since angle SGI is equal to angle ACG, that is, to ADO, and furthermore, angle SGH equals that same

ADO, and therefore both of them together, that is, the total angle IGH, are twice the angle ADO, etc.

Commentary: *In its opening lines, the Liège material introduces the word "hypotheses," which Copernicus uses in at least two distinct senses. One denotes the principal world premises, as when he states, "All of which are in completely full agreement with our hypothesis of the mobility as well as the uniformity [of motion] of the earth" (at the end of* De revolutionibus *V,10). Another, the sense used here and the one generally employed by Wittich, connotes simply a geometrical arrangement useful for computation, or what might somewhat anachronistically be called a model: "In accordance with our hypothesis, three-quarters of the entire distance lies between the centers DE, while the epicyclet receives the remaining quarter" (V,11). When this sense is implied, we will sometimes translate* **hypothesis** *as "arrangement." Note that Wittich usually labels his diagrams* **theoria**, *which is sometimes interchangeable with* **hypothesis** *and at other times refers to a collection of hypotheses; we always translate* **theoria** *as "theory." Incidentally, Maestlin adopts the same usage of* **theoria** *in his appendix to Kepler's* Mysterium cosmographicum *(1596). We shall return to the discussion of hypotheses on page 138.*

Copernicus uses a small epicycle or pair of smaller circles for various purposes in De revolutionibus*. (He sometimes distinguishes the circles by calling the smallest an "epicyclius" rather than an "epicyclus," and the word is here translated as "epicyclet.") In the planetary theory (for Venus and the superior planets) a small epicycle—together with a small additional eccentric shift of the deferent—replaces the Ptolemaic equant. In the solar theory an eccentrically placed central circlet, or an epicycle on an eccentric, or a linked pair of epicycles, is used to produce long-term changes in the eccentricity, with an associated inequality in the direction of the apsidal line. (An equant replacement is not part of the requirements for the small circles in Copernicus' solar model.) In* De revolutionibus *III,20, on the solar theory, Copernicus discusses these three possible arrangements for the pair of circles. Reinhold, in his own copy, labels them I, II, and III (see Fig. 5). In Book V Copernicus treats the planetary theory, and near the beginning of V,4, he mentions the three solar arrangements, and then, as noted in our introduction, he goes on to describe two alternative arrangements for the planets. It is these two modes that the Liège commentary has begun to explore.*

On the pages appended to the Vatican volume, Wittich begins by investigating a third, eccentreccentric mode, in which the large eccentric circle rides on an eccentrically placed central circlet. Before turning to that series, we reproduce and describe a closely related diagram within the Vatican De revolutionibus *proper, where Wittich examines for himself the two modes described in the Liège commentary.*

[f. 135 – Theory of the Superior Planets]

[to the right of the diagram]

In theoria trium superiorum, recenset Copernicus duplex genus hypotheseon. Unum eccentrepicyclon quod calculo atque observationib[us] accommodet. Alterum concentricum cum epicyclo epicycli in qua Hypothesi ponit ~~concentrici~~ epicyclum primum, motum habere aequalem suo concentrico, (ipsum deferentem), at in diversas patetur. Epicyclium vero secundum, a perigaeo suo in antecedentia dimotum, duplo velocius circumverti. Item semidiametrum epicycli II adaequare trientem epicycli I seu eccentricitatem planetae. Hac hypothesi assumta, dum centrum epicycli primi defertus a concentrico suo $\beta\gamma\alpha$*, describet* [inserted above the line: *adumbrabet*]*, tunc centrum epicycli secundi eccentricum* $\eta o \epsilon$ *suo concentrico* $\beta\alpha$ *aequalem. Sic posito centro epicycli I* [*epicyclo* overwritten *epicycli*] *in* τ *sub anomalia motus sui* $\beta\tau$*, erit sibi similis, (in ambitu praedicti epicycli),* $\psi\rho$ *tanquam motus ~~maximum~~ centri epicy[clii] II et duplum huius* $\upsilon\phi\pi$ *constituet motum planetae; praedictae* [sic for *praedicto*] *epicyclio congruentem.*

In the theory of the three superior planets Copernicus considers two kinds of arrangement: one is the eccentrepicycle, which agrees with calculations and observations, the other is the concentric with an epicycle on an epicycle. In the latter arrangement he makes the motion of the first epicycle equal to [the motion of] its concentric (the deferent itself), but going in the opposite direction [clockwise]. But the second epicyclet turns around twice as quickly, moved away from its perigee by an antecedent [counterclockwise] motion. Likewise the radius of epicycle II is equal to one-third [the radius of] epicycle I or the planet's eccentricity. Now with this arrangement assumed where the center of the first epicycle is borne around by its concentric $\beta\gamma\alpha$, then the center of the second epicycle will draw or describe an eccentric $\eta o \epsilon$ equal to its concentric $\beta\alpha$. Thus, when the center of epicycle I is located at τ in accordance with the anomaly of its motion, [arc] $\beta\tau$, there will be equal to it (in the circumference of the aforesaid epicycle [I]), [arc] $\psi\rho$ as the motion of the center of epicyclet II, and twice this [arc] $\upsilon\phi\pi$ will establish the motion of the planet appropriate to the aforesaid epicyclet.

Commentary: *The relationship of these angles is essential for understanding the models that follow. Compare, for example, this diagram for the superior planets with our redrawn scheme for the lunar theory, Figure 19 on page 95. Note that Wittich here uses "antecedentia" when he intends the counterclockwise "in consequence" motion.*

[to the right, above the diagram]

Cum centrum epicycli primi fuerit in auge vel eius opposito, erit planetae [sic] in perigaeo epicycli secundi ac sub medio transitu, in apogaeo existet.

When the center of epicycle I is in the apogee *[β]* or its opposite *[δ]*, the planet will be in the perigee of the second epicycle, but at mean passage it will be at the apogee.

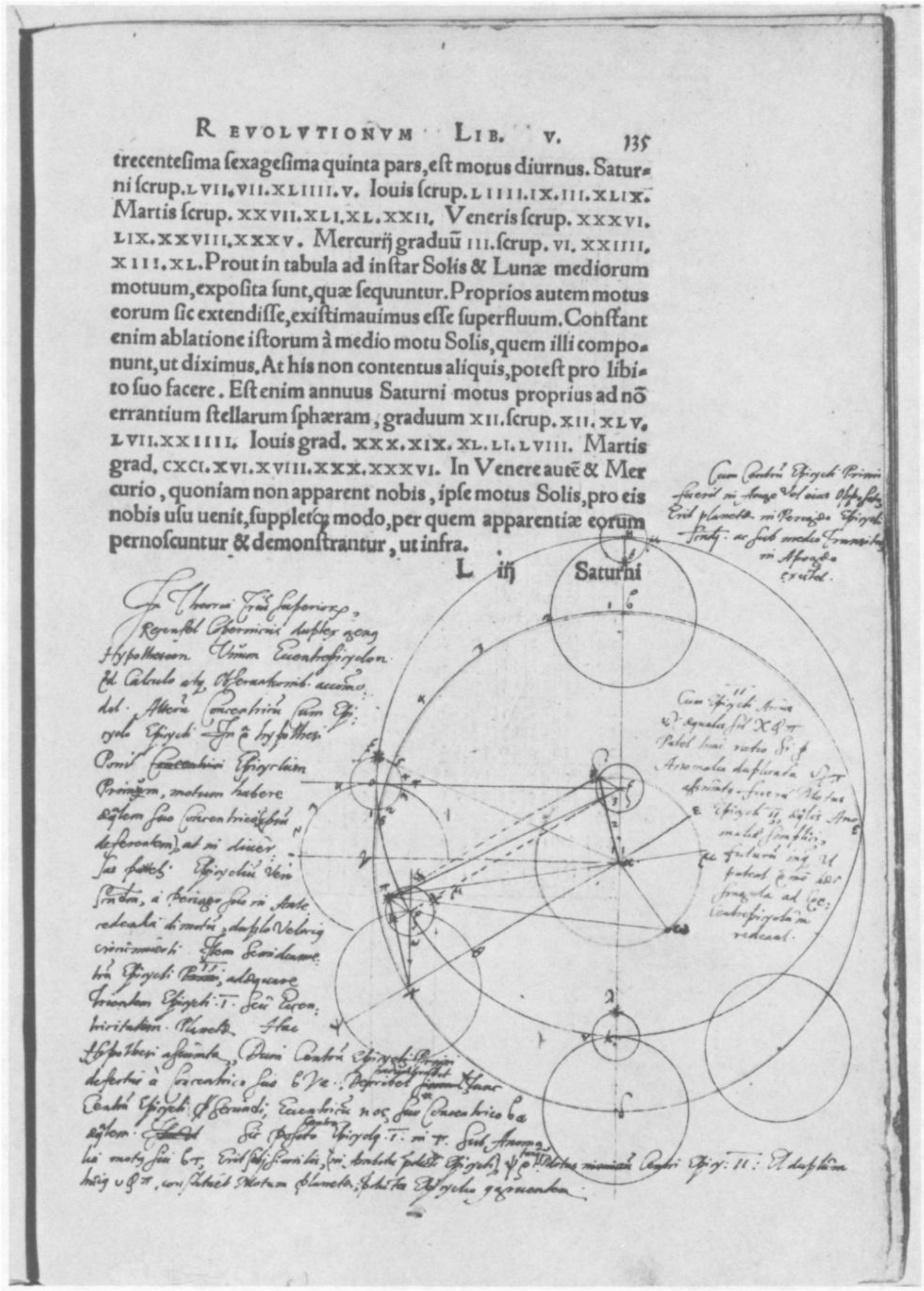
Commentary: *Note that this remark parallels and clarifies the somewhat cryptic sentence at the end of the "Secundus Modus" description in the Liège* De revolutionibus *(our page 80). The expression medio transitu is a technical term meaning 90° of mean motion from the apogee or perigee.*

[within the diagram]

Cum epicycli II arcus $\upsilon\chi$ aequalis sit $\chi\phi\pi$ patet hinc ratio si pro anomalia duplicata $\upsilon\chi\pi$ assumtus fuerit motus epicycli II aequalis anomaliae simplici, futurum inquam ut pateat quomodo haec singula ad eccentrepicyclum redeant.

Since arc $\upsilon\chi$ of epicycle II is equal to [arc] $\chi\phi\pi$, from this the reason *[for the equivalence of the two hypotheses]* is evident: if for the doubled anomaly $\upsilon\chi\pi$ the motion of epicycle II is assumed equal to the simple anomaly, I say that it will be obvious how these separate [motions] revert to the eccentrepicycle.

Commentary: *In mode two—the double epicycles riding on a concentric circle—the motion in the smaller epicycle is measured with respect to the larger epicycle's radius vector, which is constrained to lie always parallel to the apsidal line; in the diagram, the motion is given as arc $\upsilon\chi\phi\pi$, equal to the doubled mean anomaly. In mode one or the eccentrepicycle, the motion in the small epicycle is taken with respect to the radial line of the eccentric circle, $\zeta\rho$, so that the motion is in the arc $\chi\phi\pi$, which is equal to the "simple" mean anomaly $\beta\zeta\rho$. In each arrangement the planet comes out at the same place, π.*



REVOLVTIONVM LIB. V. 135

trecenteſima ſexageſima quinta pars, eſt motus diurnus. Saturni ſcrup. LVII. VII. XLIIII. V. Iouis ſcrup. LIIII. IX. III. XLIX. Martis ſcrup. XXVII. XLI. XL. XXII. Veneris ſcrup. XXXVI. LIX. XXVIII. XXXV. Mercurij graduū III. ſcrup. VI. XXIIII. XIII. XL. Prout in tabula ad inſtar Solis & Lunæ mediorum motuum, expoſita ſunt, quæ ſequuntur. Proprios autem motus eorum ſic extendiſſe, exiſtimauimus eſſe ſuperfluum. Conſtant enim ablatione iſtorum à medio motu Solis, quem illi componunt, ut diximus. At his non contentus aliquis, poteſt pro libito ſuo facere. Eſt enim annuus Saturni motus proprius ad nō errantium ſtellarum ſphæram, graduum XII. ſcrup. XII. XLV. LVII. XXIIII. Iouis grad. XXX. XIX. XL. LI. LVIII. Martis grad. CXCI. XVI. XVIII. XXX. XXXVI. In Venere autē & Mercurio, quoniam non apparent nobis, ipſe motus Solis, pro eis nobis uſu uenit, suppletq; modo, per quem apparentiæ eorum pernoſcuntur & demonſtrantur, ut infra.

L iij Saturni

Fig. 15. Vatican f. 135, the theories of the superior planets.

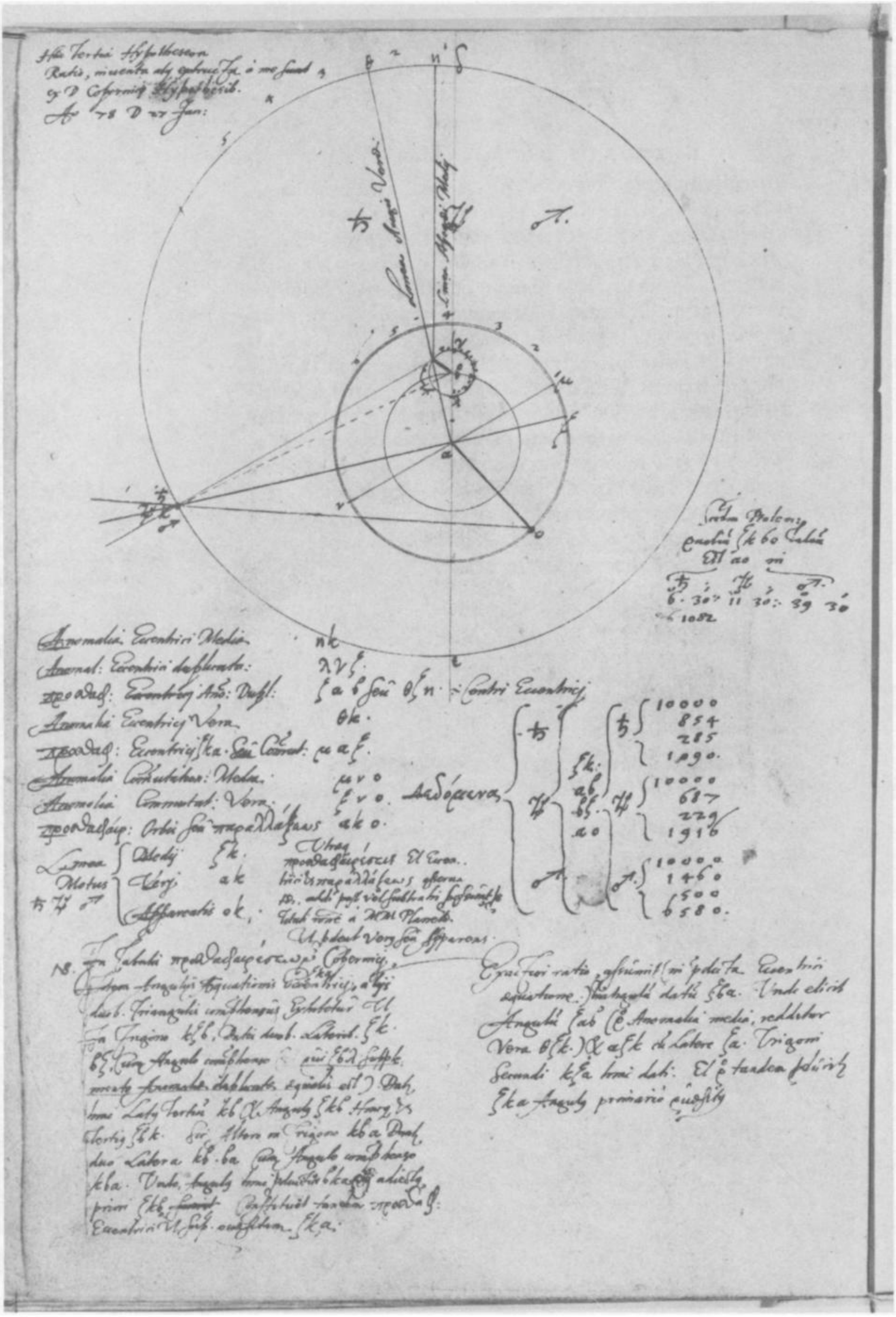


Fig. 16. Vatican f. 197v, eccentreccentric theory of the superior planets.

[f. 197v – Theory of the Superior Planets: Saturn, Jupiter, Mars]

Haec tertia hypotheseon
ratio, inventa atque extructa à me sunt
ex D Copernici hypothesib[us]. A[nn]o 78 d 27 Jan[uarii].

This third plan of the hypotheses was discovered and constructed by me from the hypotheses of Master Copernicus on 27 January [15]78.

[on the diagram]

Linea augis verae	Line of true apogee
Linea apogaei medii	Line of mean apogee

Commentary: *The diagram shows the position of a superior planet on the outer circle, the orbit of the earth with the middle circle drawn with the doubled line (a convention Wittich adopts throughout for the orbis magnus), and the central double-circle mechanism that produces the planet's equation of the eccentric, i.e., the mechanism approximately equivalent to the Ptolemaic equant. Wittich calibrates part of the circumference to indicate the direction and relative speeds of motion.*

[right of the diagram]

Secundum Ptolemaei qualium ζκ 60 talium est αο in

[Sat]	*[Jup]*	*[Mar]*
6°30'	*11°30'*	*39°30'*
1082		

According to Ptolemy, when *ζκ* is 60 parts, then *αο* is …
[$6^p30'/60 = .1082$, that is, the relative sizes of the orbital circles. The two missing entries should be 1916 and 6583, nearly matching the Copernican values in the bracketed table below.]

[below the diagram]

Anomalia eccentrici media	*ηκ*	Mean eccentric anomaly
Anomal[ia] eccentrici duplicata:	*λγζ*	Doubled eccentric anomaly
Προσθαφ[αίρεσις] eccentrici		Prosthaphaeresis [or equation]
anom[alia] dupl[icata]	*ζαβ*	of doubled eccentric anomaly
seu θζη, i.e. centri eccentrici		or of center of the eccentric
Anomalia eccentrici vera	*θκ*	True eccentric anomaly
Προσθαφ[αίρεσις] eccentrici	*ζκα*	Equation of the eccentric
seu commut[atio]	*μαξ*	or of the parallax
Anomalia commutation[is] media	*μνο*	Mean anomaly of the parallax
Anomalia commutat[ionis] vera	*ξνο*	True anomaly of the parallax
Προσθαφαίρ[εσις] orbis seu		Equation of the [earth's] orb or
παραλλάξεως	*ακο*	of the parallax

Commentary: *In the tabulation above, Wittich sometimes gives arcs, such as $\lambda\gamma\zeta$ or $\mu\nu o$, and sometimes angles, such as $\zeta\alpha\beta$ or $\zeta\kappa\alpha$. He has placed the earth at o, and the parallax is the annual effect on the apparent position of the superior planet caused by the moving position of the earth in its orbit. Copernicus uses both "commutatio" and the Greek "parallaxis," both of which are translated "parallax," just as both "equatio" and the Greek "prosthaphairesis" are here translated as "equation."*

Linea *Motus* *[S][J][M]*	*Medii*	$\zeta\kappa$	*Utraque προσθαπθαίρεσεις et Eccentrici & παραλλάξεως asservatae, addi post vel subtrahi possunt, pro totali ratione à m[edio] m[otu] planetae. Ut prodeat verus seu apparens.*
	Veri	$\alpha\kappa$	
	Apparentis	$o\kappa$	

Line of	mean	$\zeta\kappa$	motion of Saturn, Jupiter, and Mars
	true	$\alpha\kappa$	
	apparent	$o\kappa$	

If both the eccentric and parallactic equations are saved, they can then be added afterward or subtracted so as to get the entire result from the planet's mean motion in order to find the true or apparent [motion].

Δεδόμενα Data	*[Sat]* *[Jup]* *[Mar]*	$\zeta\kappa$ $\alpha\beta$ $\beta\zeta$ αo	*[Sat]*	10000 854 285 1090
			[Jup]	10000 687 229 1916
			[Mar]	10000 1460 500 6580

[Wittich has transcribed this Copernican data from three marginal tables labeled δεδόμενα in the Liège De revolutionibus*, ff. 149, 154v, and 159v respectively.]*

NB. In tabulis προσθαφαιρέσεων Copernici, idem angulus aequationis eccentrici $\zeta\kappa\alpha$,* *aliis duob[us] triangulis comprehensus exhibetur. Ut in trigono* $\kappa\zeta\beta$, *datis duob[us] laterib[us]* $\zeta\kappa$. $\beta\zeta$, *cum angulo comprehenso (qui* $\zeta\beta\lambda$ *supplemento anomaliae duplicatae aequalis est). Datur hinc latus tertium* $\kappa\beta$ *& angulus* $\zeta\kappa\beta$ *haecque & tertius* $\zeta\beta\kappa$. *Sic altero in trigono* $\kappa\beta\alpha$ *dantur duo latera* $\kappa\beta.\beta\alpha$ *cum angulo comprehenso* $\kappa\beta\alpha$. *Unde angulus hinc producitur* $\beta\kappa\alpha$ *qui adjectus priori* $\zeta\kappa\beta$ ~~*fuerit*~~ *constituit tandem προσθαφ[αίρεσιν] eccentrici ut supra quaesitum* $\zeta\kappa\alpha$.

NB. In Copernicus' tables of equations, this same angle of the equation of the eccentric, $\zeta\kappa\alpha$, is shown contained by two different triangles. So, in triangle $\kappa\zeta\beta$, given the two sides $\zeta\kappa$ and $\beta\zeta$ with the included angle [i.e., $\kappa\zeta\beta$] (which is equal to the supplement of the doubled anomaly $\zeta\beta\lambda$), then the third side $\kappa\beta$ is given and the angle $\zeta\kappa\beta$ and the third [angle] $\zeta\beta\kappa$. Thus, in the other triangle, $\kappa\beta\alpha$, the two sides $\kappa\beta$ and $\beta\alpha$ are given with the included angle $\kappa\beta\alpha$. From this angle $\beta\kappa\alpha$ is found, which, added to the earlier $\zeta\kappa\beta$, finally yields the eccentric equation $\zeta\kappa\alpha$ that was sought above.

Commentary: *In each of the models the motion in the small circle or epicyclet is linked with the mean anomaly. Here the linkage is clearly identified in Wittich's main list under the diagram. Angle* $\eta\zeta\kappa$ *is the mean anomaly, and arc* $\lambda\gamma\zeta$ *is twice the mean anomaly. Hence* $\kappa\zeta\beta$ *is also the mean anomaly, but Wittich mistakenly identifies it with* $\zeta\beta\lambda$, *which is, as he says, the supplement of the doubled anomaly.*

* *[inserted in the text above:]*
Exactior ratio, assumit (in praedicta eccentrici aequatione) triangulum datum $\zeta\beta\alpha$. *Unde elicit angulum* $\zeta\alpha\beta$ *(quo anomalia media, redditur vera* $\theta\zeta\kappa$*) &* $\alpha\zeta\kappa$ *cum latere* $\zeta\alpha$. *Trigoni secundi* $\kappa\zeta\alpha$ *hinc dati. Et quo tandem producitur* $\zeta\kappa\alpha$ *angulus primariò quaesitus.*

A more exact procedure takes as its starting point (in the aforesaid equation of the eccentric) the given triangle $\zeta\beta\alpha$ from which it finds angle $\zeta\alpha\beta$ (by which the mean anomaly is reduced to the true $\theta\zeta\kappa$), and $\alpha\zeta\kappa$ with the side $\zeta\alpha$ of the second triangle $\kappa\zeta\alpha$ are thus given. And finally from that the angle primarily sought, $\zeta\kappa\alpha$, is found.

[f. 198 – Solar Theory]

Commentary: *The arrangement shown here is called by Copernicus (III,20, f. 91) "eccentreccentric" and is labeled by Reinhold the "first mode"; it corresponds to the differently-numbered third mode that Wittich has just devised for the superior planets. Wittich draws the third and second solar modes on ff. 201v and 205v respectively.*

γζ	*Anomalia aequinoctiorum simplex seu apogaei solaris anomalia media*	Simple anomaly of the equinoxes or mean anomaly of the solar apogee
βαζ *seu* ηζθ	*Προσθαφ[αίρεσις] centri eccentrici*	Equation of eccentric center
ηδκ	*Anomalia Solis media*	Mean anomaly of the sun
θδκ	*Anomal[ia] Solis vera*	True anomaly of the sun
ζκα	*Προσθαφαίρεσις orbis*	Equation of the orb

Linea motus Solis Line of solar motion	*Medii*	κζ	Mean
	Apparentis ~~seu~~ et veri	κα	Apparent and true

Δεδόμενα Data	ζκ	*100000*
	βα	*3694*
	βζ	*475*

Assumpta anomalia apogaei sub initio 57^{A} 000^{D} *Ante Christum*
Sol ut à me correcta ad annum 1501:
Assuming that the anomaly of the apogee begins at 57 years 0 days before Christ, the sun as corrected by me to the year 1501:

	2′ 43° 25′ et	*[Anomaly of the equinoxes]*
Eccentricitate ζα ~~2~~	*1° 56′ 44″*	*[= 3242]*
Maxima vero	*2° 30′ 30″*	True maximum [eccen.] *[= 3212]*
Elicietur hinc βαζ	*2° 25′ 40″*	Whence βαζ comes to be 2°;25,40
pro βζ 17′ 21″ et βα	*2° 13′ 10″*	for βζ = ;17,21 and βα = 2^{p};13,10
Item λα	*2° 55′ 48″*	*[sic for 1°]* Likewise λα = 1^{p};55,48
		[Minimum eccen. = 3217]

Hinc constituto apogaeo vero θα in 7° 30′ 2″ Cancri
Erit locus apogaei medii δα in 9° 55′ 42″.

Thus by setting the true apogee θα in 7° 30′ 2″ of Cancer
the place of the mean apogee δα will be in 9° 55′ 42″.

Commentary: *The anomaly of the equinox of 163° 25′ for 1558 Julian or 1559 Egyptian years is found by computation from the tables in* De revolutionibus *III,6. (Wittich ignores the "completed year" convention and the A.D./B.C. tradition that omits the year zero.) The eccentricity for 1501 is readily obtained from the* Prutenicae tabulae *as 3242, corresponding to the sexagesimal given by Wittich. The maximum eccentricity of* 2^{p}*;30,30 =* 0^{p}*;17,21 +* 2^{p}*;13,10 and the minimum (λα) of* 1^{p}*;55,48 correspond to βα = 3699 and βζ = 482 rather than the values*

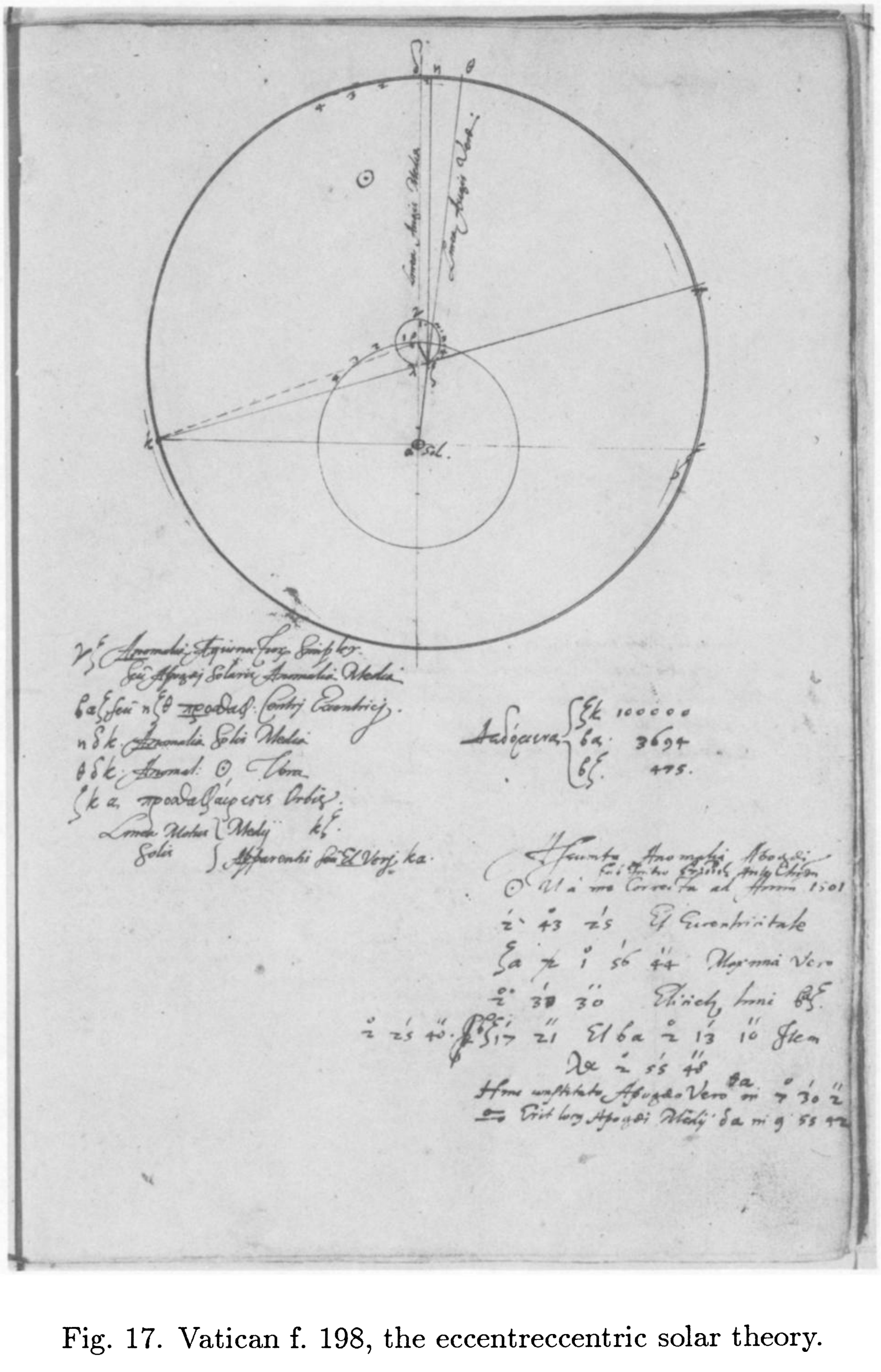


Fig. 17. Vatican f. 198, the eccentreccentric solar theory.

in the data table above. The solution of triangle $\alpha\beta\zeta$ leads to 2° 25′ 40″ for the equation angle $\beta\alpha\zeta$, and this is reflected in the difference between the true and mean apogees.

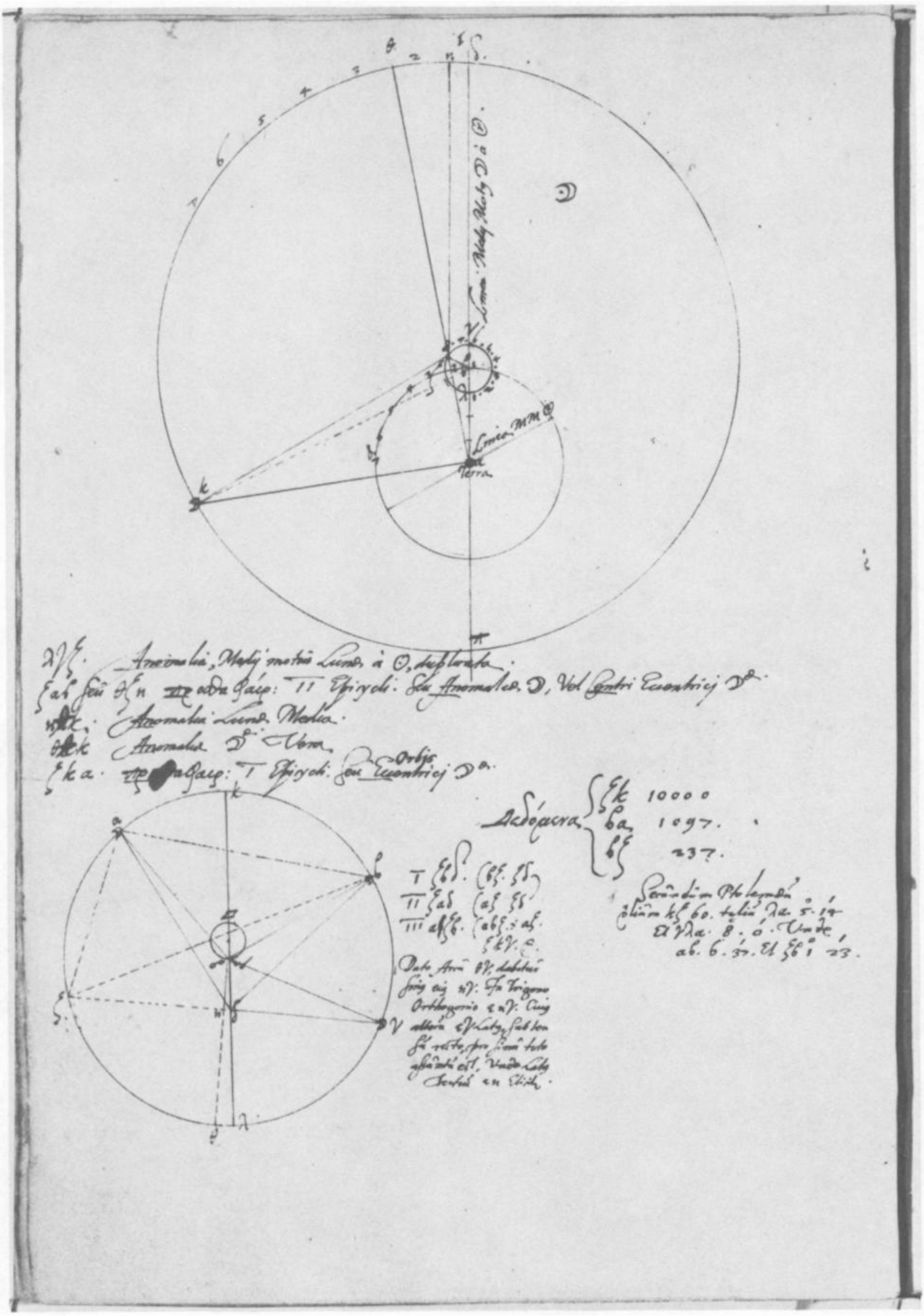


Fig. 18. Vatican f. 198v, the eccentreccentric lunar theory.

[f. 198v – Lunar Theory]

[on the main diagram]

Linea medii motus Lunae à Sole. Line of mean lunar elongation.
[sic: actually the line of mean lunar apogee.]

Linea m[edii] m[otus] Solis. Line of mean solar motion.
[sic: actually the line of mean lunar motion.]

[under the main diagram]

λγζ *Anomalia, medii motus Lunae à Sole, duplicata.*
Arc λγζ, doubled mean anomaly of lunar elongation.

ζαβ *seu* θζη Προσθαφαίρ[εσις] *II epicycli seu anomaliae Lunae, vel centri eccentrici Lunae.*
ζαβ or θζη Equation of the second epicycle or of the lunar anomaly, or of the center of the lunar eccentric.

ηκ *Anomalia Lunae media.* Mean lunar anomaly.
θκ *Anomalia Lunae vera.* True lunar anomaly *[with respect to the epicyclet only].*

ζκα Προσθαφαίρ[εσις] *I epicycli seu eccentrici orbis Lunae.*
Equation of the first epicycle or of the eccentric of the lunar orb.

Commentary: *In both the Ptolemaic and Copernican lunar models, the major peculiarities of the lunar motion are accounted for with two subsidiary circles. Ptolemy used an epicycle, rotating counterclockwise, to produce the eccentricity of the orbit as well as the nine-year rotation of the apsidal line. He noticed that when the moon was near its quarter phases, a larger epicycle seemed to be required. This effective change in the eccentricity at quadratures is called evection. Ptolemy used a larger central crank circle, rotating counterclockwise at the elongation rate, to bring the epicycle closer to the earth at the quadratures. Copernicus solved the problem differently, by using an epicyclet on the epicycle to make the epicycle effectively bigger at the quadratures. Wittich, in his three lunar diagrams (here, and ff. 202 and 206), follows the roles that Copernicus assigned for the small circles, placing the epicycles in each of three possible arrangements. Wittich draws and correctly labels the Copernican arrangement on f. 206. Here, however, in one of the alternative schemes, he confuses several of the lines. Since the direction of the perigee is controlled by the larger secondary circle, αδ must be the line of mean apogee and the unlabeled θα is the line of true apogee. Also, if we assume that the doubled elongation in the epicyclet is correctly* *placed, then the line of mean solar motion would lie as shown in our redrawn figure, and what Wittich has called the line of mean solar motion is actually parallel to* $\zeta\kappa$ *and thus the line of mean lunar motion. Note that Wittich has drawn the doubled elongation as 240° and the mean anomaly as 120°, so that the mean anomaly equals the elongation. In the redrawn figure the mean anomaly has been changed to 100° in order to distinguish the quantities more readily.*

[below the diagram to the right]

Δεδόμενα Data		
	$\zeta\kappa$	*10000*
	$\beta\alpha$	*1097*
	$\beta\zeta$	*237*

Secundum Ptolemaeum qualium $\kappa\zeta$ *60 talium* $\lambda\alpha$ *5° 14′*
et $\gamma\lambda\alpha$ *8° 0′. Unde* $\alpha\beta$ *6° 37′et* $\zeta\beta$ *1° 23′.*
According to Ptolemy, if $\kappa\zeta$ is 60, $\lambda\alpha$ is 5^{p};14 and $\gamma\lambda\alpha$ is 8^{p};0. From this $\alpha\beta$ is 6^{p};37 and $\zeta\beta$ is 1^{p};23.

Commentary: *Wittich has transferred this data from f. 112 of his Liège* De revolutionibus *(see below) where he also gives the sexagesimal equivalent, which can be compared with Ptolemy's spacings from* Almagest V,7 *(in the text immediately above):*

Δεδόμενα *Copernici*						
	CD	*10000*	*60°*			
	CE	*1097*	*6*	*34′*	*55″*	*12‴*
	EG	*237*	*1*	*25*	*14*	*13*

[with the secondary diagram]

I. $\zeta\beta\delta$ $(\beta\zeta.\zeta\delta$
II. $\zeta\alpha\delta$ $(\alpha\zeta\ \zeta\delta)$
III. $\alpha\zeta\beta$ $(\alpha\beta\zeta$*, id est* $\alpha\zeta.\zeta\kappa\gamma$ *q[uaesitum])*

Dato arcu $\theta\gamma$*, dabitur sinus eius* $\eta\gamma$*. In trigono orthogonio* $\epsilon\eta\gamma$ *cuius alterum* $\epsilon\gamma$ *latus, subtensum recto, pro sinu toto assumtum est. Unde latus tertium* $\epsilon\eta$ *elicitur.*

Given the arc $\theta\gamma$, its sine $\eta\gamma$ is given. In the right triangle $\epsilon\eta\gamma$ one side of which, $\epsilon\gamma$, subtending the right angle, is taken for the total sine *[i.e., the sine of the right angle]*. From this the third side $\epsilon\eta$ is found.

Commentary: *Wittich does not identify the second diagram, but it derives from the "problem of three observations" in* De revolutionibus *IV,5, where the positions of three lunar eclipses (*α*,* β*, and* γ*) are used to calculate the eccentricity, or equivalently, the size of the first epicycle.*

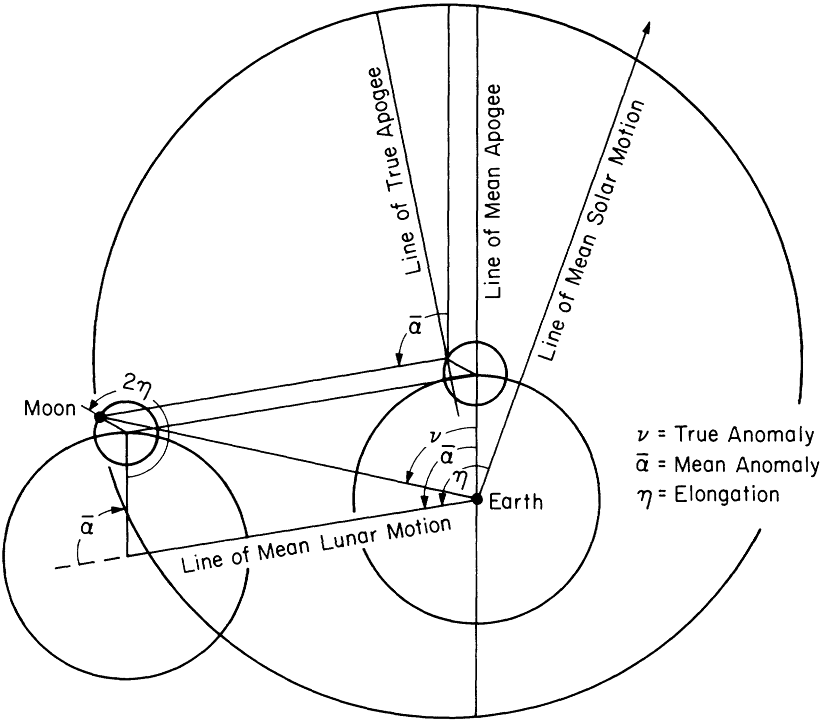


Fig. 19. Redrawn version of Vatican f. 198v.
Compare also with the Copernican lunar theory on f. 206, Fig. 34, as well as Wittich's diagram for the superior planets in Fig. 15, p. 85.

[f. 199 – Venus]

[right of the diagram]

Ptolemaeo est ζκ 43° 10′ qualium βο 60.
Ptolemy has 43^{p};10 for *ζκ* when *βο* is 60^{p} *[=.7194].*

Anomalia eccentrici media	*δο*	Mean eccentric anomaly
Anomalia eccentrici duplicata	*γλζ*	Doubled eccentric anomaly
Προσθαφαίρ[εσις] centri eccentrici	*βαζ* ~~*θαδ*~~	Equation of the center of the eccentric
Anomalia vera	*θο*	True anomaly
Προσθαφ[αίρεσις] eccentrici seu commutat[ionis]	*αοζ* *μζξ*	Equation of the eccentric or of the parallax
Anomalia commutationis mediae	*μνκ*	Mean anomaly of the parallax
Anomalia commutationis verae	*ξμκ*	True anomaly of the parallax
Προσθαφ[αίρεσις] orbis seu παραλλάξεως	*ζοκ*	Equation of the orb or of the parallax

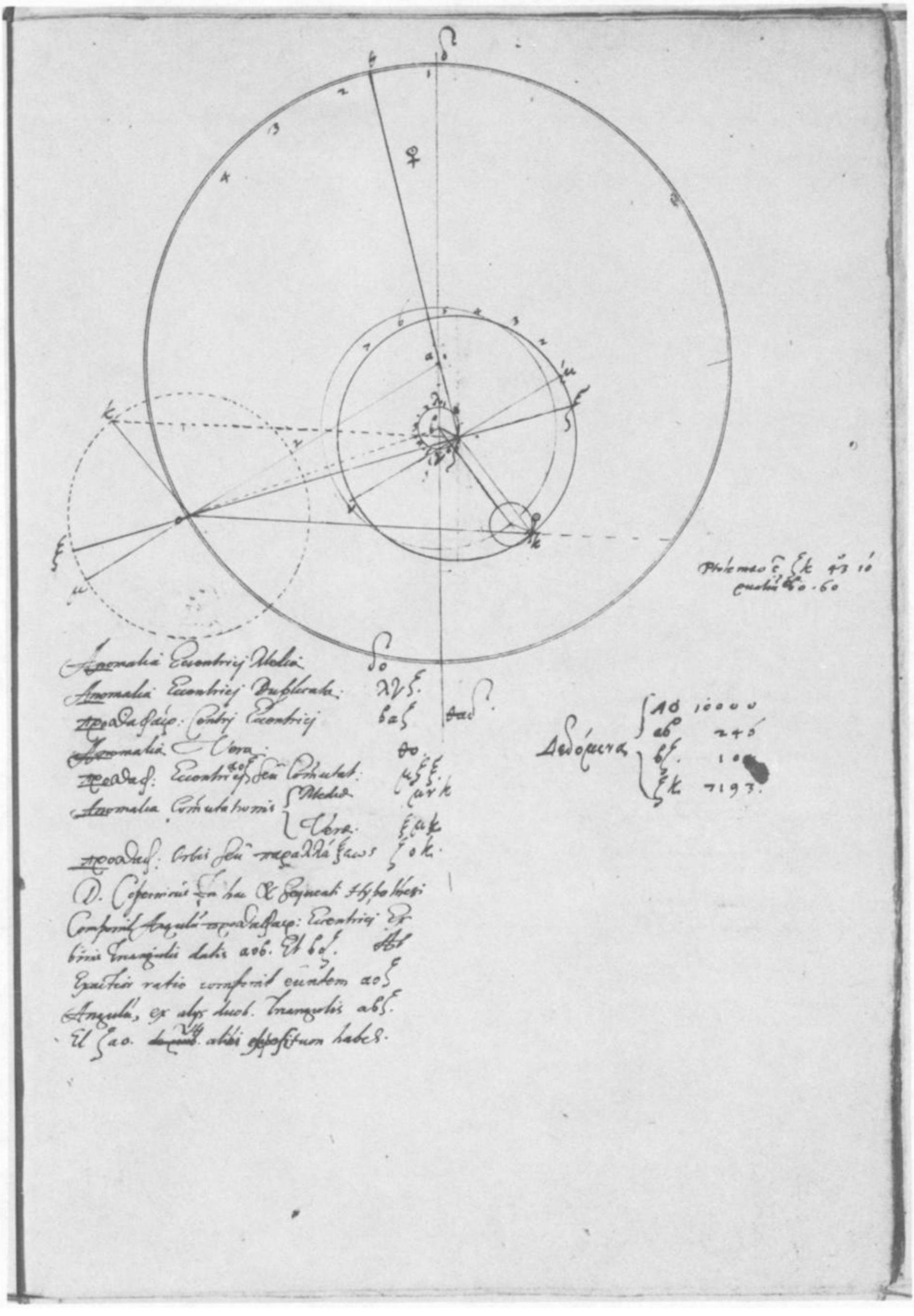
D. Copernicus in hac & sequenti hypothesi componit angulum προσθαφαιρ[έσεως] eccentrici ex binis triangulis datis αοβ et βοζ. At exactior ratio componit eundem αοζ angulum, ex aliis duob[us] triangulis αβζ et ζαο ut alibi expositum habes.

Master Copernicus in this and the following arrangement puts the angle of the eccentric equation together from the two given triangles *αοβ* and *βοζ*. But a more exact calculation takes the same angle *αοζ* from the two triangles *αβζ* and *ζαο*, as you have it shown elsewhere.

Δεδομενα Data	*αο*	*10000*
	αβ	*246*
	βζ	*104*
	ζκ	*7193*

Commentary: *For Venus, the transformation from a geocentric Ptolemaic arrangement to a heliocentric Copernican plan is not as simple as for the superior planets because the equation of the center depends on the motion of the earth rather than on the planet; to be consistent with the superior planets Venus should have its own eccentricity and equations. Copernicus' final model places the small auxiliary circle in the middle, as shown here together with Wittich's initial parallelogram transformation. The Copernican model could be called "eccentreccentric" whereas Wittich's transformation of it is actually in the second, "eccentrepicyclic," mode.*

Note that the first two entries in Wittich's table are arcs, and that the angle in the small central circle (measured counterclockwise) is twice



Anomalia Eccentrici Media. δο

Anomalia Eccentrici Duplicata. λγζ.

προσθαφαίρεσις Centri Eccentrici βαζ θαδ.

Anomalia Vera. θο.

προσθαφ. Eccentri aoζ seu Commutat. μζξ.

Anomalia Commutationis { Media ζμκ; Vera. ξμκ

προσθαφ. Orbis seu παραλλάξεως ζοκ.

D. Copernicus in hac et sequenti Hypothesi Comperit ~~Angulum προσθαφαίρεσις~~ Eccentrici ex ... trianguli datis aob. et boζ. ... Eadem ratio comperit eundem aoζ Angulum, ex aliis duob. triangulis abζ. Et ζao. ~~[illegible]~~ alibi expositum habes.

Δεδομένα { αο 10000; αβ 246; βζ 10; ζκ 7193.

Fig. 20. Vatican f. 199, two theories of Venus.

the mean anomaly carrying the earth at o around the mean sun at α. The obscured number for $\beta\zeta$ in the bracketed list is readily found in a similar table in the margin of f. 163v of Wittich's Liège De revolutionibus. *Copernicus' 7193 for $\zeta\kappa$ matches Ptolemy's sexagesimal value at the top.*

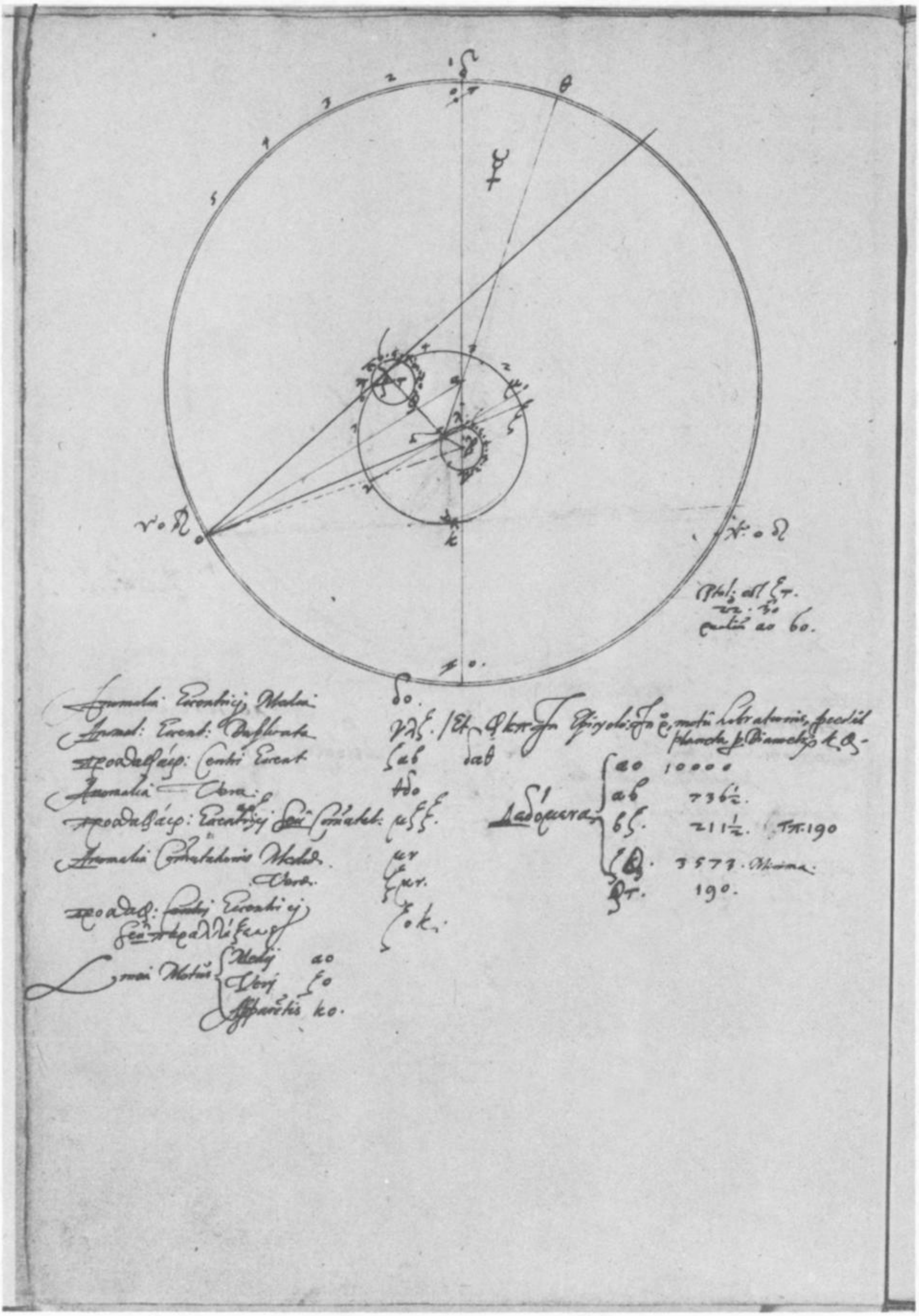


Fig. 21. Vatican f. 199v, the theory of Mercury.
Reinhold refers to this Copernican arrangement (De revolutionibus V,15) as the "eccentrici-eccentric-eccentrepicyclic" mode.

[f. 199v – Mercury]

[right of the diagram]

Ptol[emaeus] est ζτ 22° 30′ qualium αο 60.
Ptolemy has $22^p;30$ for ζτ when αο is 60^p *[the size of the Ptolemaic epicycle in Almagest IX,9].*

[below the diagram]

Anomalia eccentrici media	δο	Mean eccentric anomaly
Anomal[ia] eccent[rici] duplicata et φκπ in epicyclo in quo motu librationis procedit planeta per diametrum κφ.	γλζ	Doubled eccentric anomaly and φκπ in the epicycle in which, by the motion of libration, the planet proceeds along the diameter κφ.
Προσθαφαίρ[εσις] centri eccent[rici]	ζαβ δαθ	Equation of the eccentric center
Anomalia vera	θδο	True anomaly
Προσθαφαίρ[εσις] eccentrici seu commutat[ionis]	αοζ μζξ	Equation of the eccentric or of the parallax
Anomalia commutationis mediae	μν	Mean anomaly of parallax
verae	ξμν	True anomaly of the parallax
Προσθαφ[αίρεσις] ~~centri~~ eccentrici seu παραλλάξεως	ζοκ	Equation of the eccentric or of the parallax

Linea motus Line of motion	*Medii*	αο	Mean
	Veri	ζο	True
	Apparentis	κο *[sic πο]*	Apparent

Δεδόμενα Data	αο	*10000*	
	αβ	*736½*	
	βζ	*211½*	*τπ 190*
	ζφ	*3573*	*minima*
	φτ	*190*	

Commentary: *This, the first of five diagrams that Wittich devoted to Mercury, depicts the "standard" Copernican model for the planet closest to the sun. Following Ptolemy, Copernicus used two small auxiliary circles to generate a double perigee for Mercury. The innermost circle lies along a mean apsidal line, displaced from the center of the earth's orbit, and it determines the instantaneous center of Mercury's main orb and hence Mercury's true apsidal line. The counterclockwise motion in the small central circle is the doubled mean anomaly; on the diagram Wittich has δαο = 120° and arc γλζ = 240°, very convenient for drafting purposes. The counterclockwise motion in the second small circle is also* *the doubled mean anomaly, so here the numbered arc between ϕ and π also equals 240°. As Wittich states, the planet does not follow the second small circle, but rather, it librates along that diameter—the planet is therefore on the intersection of the line from o through the outlying epicycle and the extension of line $\zeta\phi$, at a point somewhat unclearly marked κ. In other words, the libration of the planet in the second small circle determines the instantaneous size of Mercury's main orb. The true line of sight from the earth to Mercury is along $o\kappa$. The second κ appearing on the apsidal line is spurious, presumably a fossil relating to an erased line from o.*

Wittich gives alternative hypotheses for Mercury on ff. 203 and 207; the latter may have been catalytic in turning him toward the geocentric versions on ff. 209 and 210.

[f. 200 – Venus]

Commentary: *This unlabeled, and therefore somewhat cryptic, diagram most closely resembles the Venus construction on f. 199; it does not go beyond that one, and might possibly have been drawn in conjunction with it, especially if f. 199 has more than one stage. This diagram also seems to anticipate the extensive parallelogram constructions of ff. 203v, 204, and 204v, done just a few days later.*

[f. 200v – Superior planets]

Commentary: *The most interesting feature of this diagram is the word Terra in the middle, signaling Wittich's interest in a geocentric arrangement that will become more fully developed in two weeks. No double-line circle is needed since the earth is at the center. Wittich has placed the Copernican epicyclet for the superior planets onto the Ptolemaic epicycle for the planet's second inequality. Since the motion of the angle in the epicyclet is not uniform with respect to the earth, Wittich seems to have lost track of the planet's position in the epicyclet.*

[f. 201 – Superior planets]

Theoria trium superiorium quam assumsit Copernicus.
Theory of the three superior planets as Copernicus assumed.

Commentary: *Cf. f. 197v. The smallest circle has here been transferred to the deferent, representing the so-called first mode, the arrangement actually adopted in* De revolutionibus. *He also draws part of an epicycle equivalent to the eccentricity $\alpha\beta$, presaging the second mode that will be explicated on f. 205. By mistake Wittich here uses the letter δ twice.*

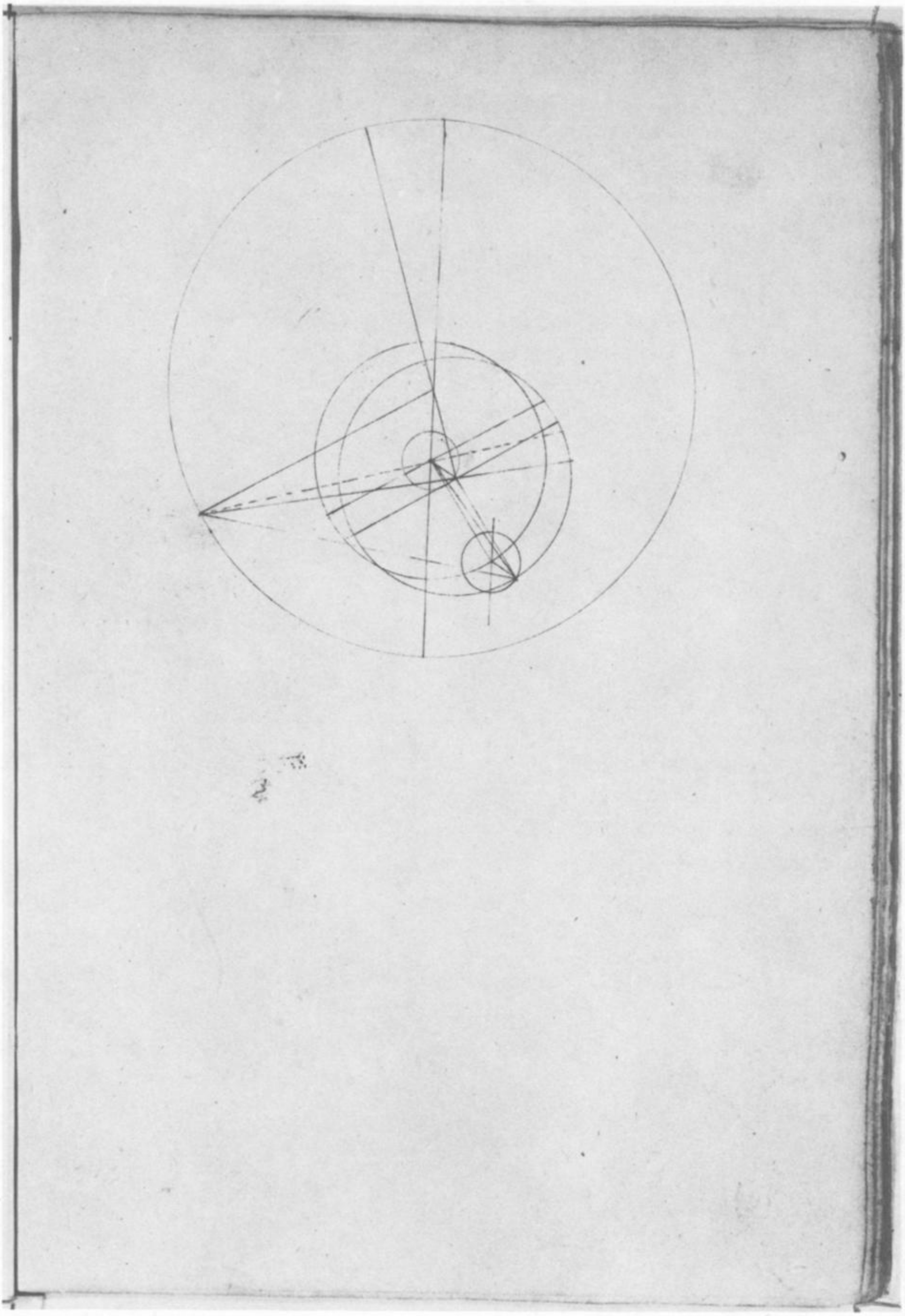


Fig. 22. Vatican f. 200, an unfinished sketch for the theory of Venus.

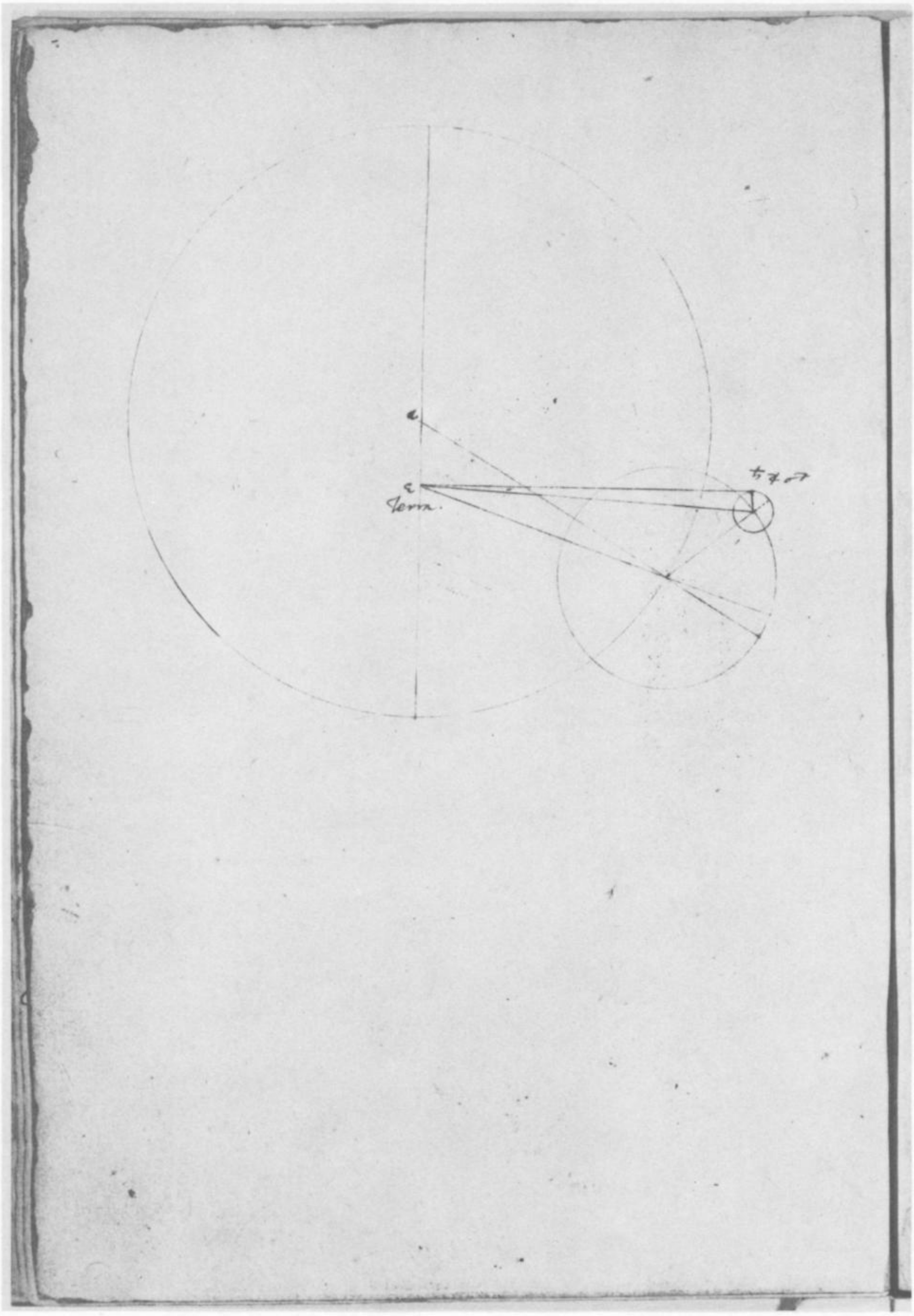


Fig. 23. Vatican f. 200v, a geocentric theory of the superior planets.

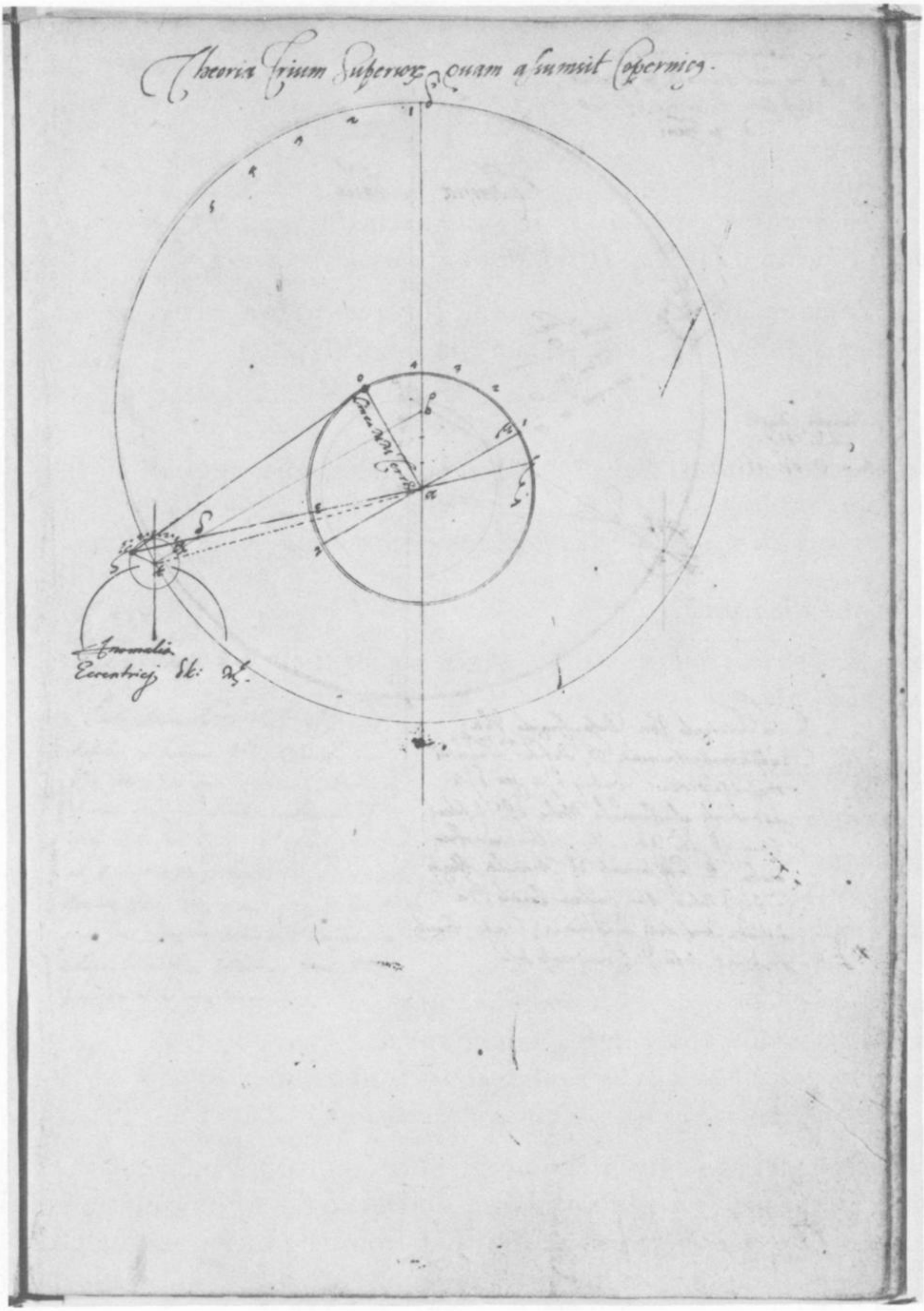


Fig. 24. Vatican f. 201, eccentrepicyclic theory of the superior planets.

[on the diagram]

Linea m[edii] m[otus] Terrae.	Line of the earth's mean motion.
Anomalia eccentrici δκ λζ	Eccentric anomaly

[f. 201v – Solar Theory]

Theoria Solis

[upper left corner]

Hae subsequentes theoriae à me sunt derivatae ex precedenti hypothesi Copernici a[nn]o [15]78. D[ie] 30 Jan[uarii].

On 30 January 1578, these following theories were derived by me from Copernicus' preceding arrangement [i.e., f. 201].

[on the diagram]

Linea m[edii] m[otus] Solis	Line of mean solar motion
veri m[otus] Solis	Line of true solar motion
apparenti m[otus] Solis	Line of apparent solar motion

[left of the diagram]

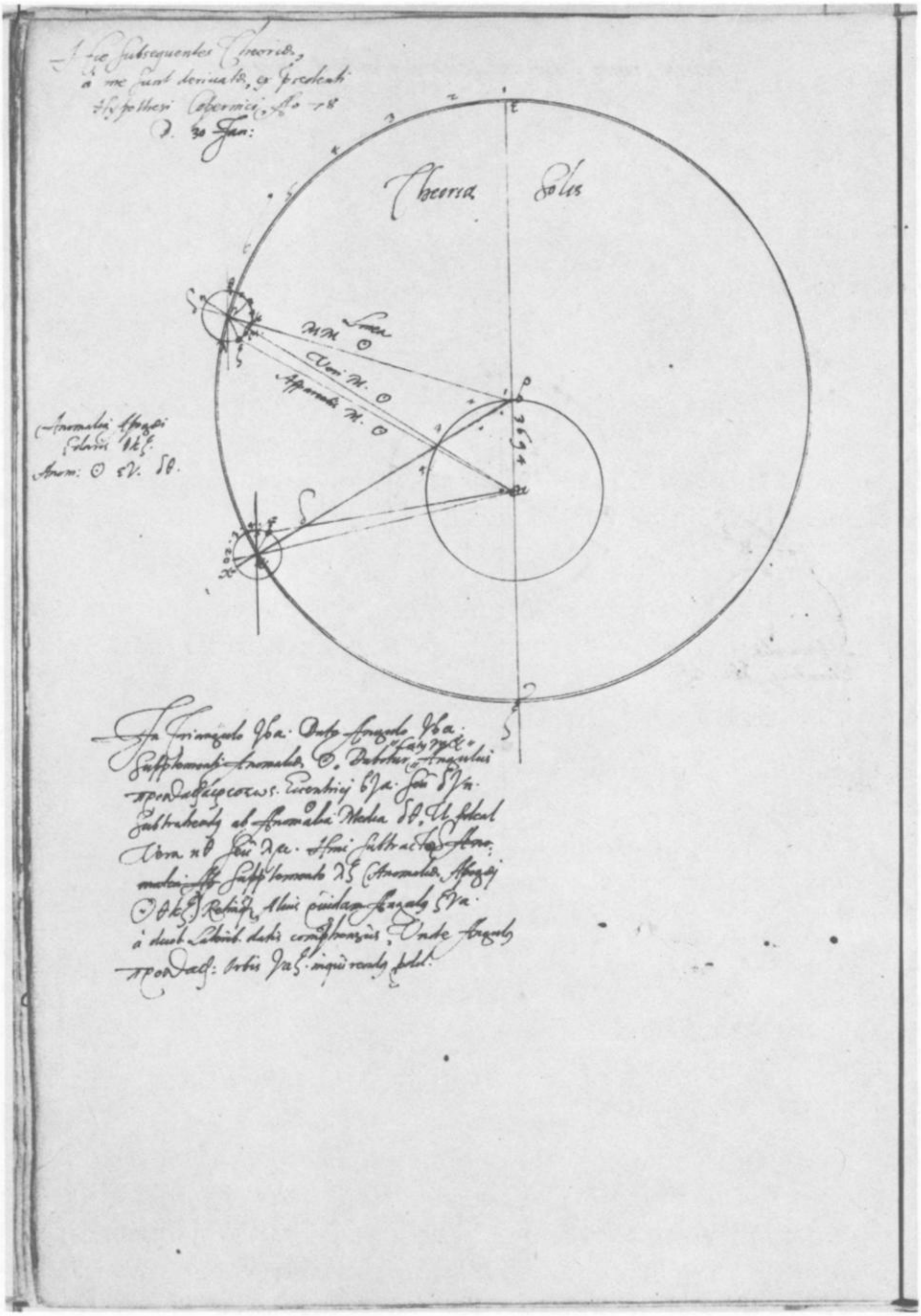
Anomalia apogaei solaris $\theta\kappa\zeta$	Anomaly of the solar apogee
Anom[alia] Solis $\epsilon\gamma$. $\delta\theta$	Solar anomaly

[below the diagram]

In triangulo $\gamma\beta\alpha$ *dato angulo* $\gamma\beta\alpha$
supplementi anomaliae Solis. Dabitur latus $\gamma\alpha$ *& angulus*
προσθαφαίρεσεως eccentrici $\beta\gamma\alpha$ *seu* $\delta\gamma\eta$.
Subtrahendus ab anomalia Solis media $\delta\theta$, *ut prodeat*
vera $\eta\theta$ *seu* $\lambda\mu$. *Hinc subtracto ~~ano~~*
~~malia ab~~ supplemento $\lambda\zeta$ *(anomaliae apogaei*
Solis $\theta\kappa\zeta$*). Relinquitur alius quidam angulus* $\zeta\gamma\alpha$
à duob[us] laterib[us] datis comprehensus, unde angulus
προσθαφ[αιρέσεως] orbis $\gamma\alpha\zeta$ *inquirendus prodat.*

In the triangle $\gamma\beta\alpha$, given the angle $\gamma\beta\alpha$ (the supplement of the solar anomaly), the side $\gamma\alpha$ will be given, and the angle of the equation of the eccentric $\beta\gamma\alpha$ or $\delta\gamma\eta$. Subtracting that from the mean anomaly of the sun, arc $\delta\theta$, there results the true anomaly arc $\eta\theta$ or $\lambda\mu$. Subtracting from this the supplement $\lambda\zeta$ (of the anomaly of the solar apogee $\theta\kappa\zeta$) there remains a certain other angle $\zeta\gamma\alpha$ *[*$=\zeta\gamma\mu$*]* included between two given sides, from which the sought-for angle of the equation of the orb, $\gamma\alpha\zeta$, follows.

Commentary: *Copernicus calls this arrangement, the third described in* De revolutionibus *III,20, the "eccentrepicycle"; it corresponds to the so-called first mode for the superior planets, as shown on the preceding diagram.*



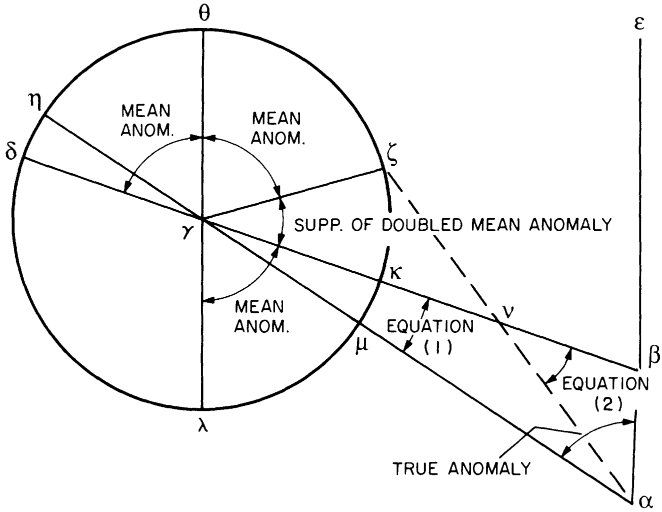
Hae subsequentes Theoriae,
à me sunt derivatae, ex praecedenti
Hypothesi Copernici, Ao 78
d. 30 Jan:

Theoria Solis
3694

Fig. 25. Vatican f. 201v, the eccentrepicyclic solar theory.

Note: the size of the inner circle is specified as 3694 parts, agreeing with the Copernican data given on f. 198 (our p. 90).

[f. 202 – Lunar Theory]



Theoria Lunae

[left of the diagram]

$\gamma\zeta$ *237*

Anomalia Lunae $\epsilon\gamma.\delta\theta$
Lunar anomaly

Longit[udo] Lunae
à Sole dupli[cata] $\lambda\mu\zeta$
Doubled elongation

[on the diagram]

Linea m[edii] m[otus] Lunae à Sole
Line of mean elongation *[actually, the line of mean lunar apogee].*

Linea m[edii] m[otus] solis *1097*
Line of mean motion of the sun *[and* 1097, *the Copernican radius of the larger epicycle that controls the direction of the apsidal line].*

[left below the diagram]

Data anomalia Lunae media $\epsilon\beta\gamma$ $(\delta\theta\zeta)$ *dabitur in trigono* $\gamma\beta\alpha$, *aequatio* ~~*ip*~~ *illius* $\beta\gamma\alpha$ *seu* $\delta\gamma\eta$: *quae constituet anomaliam veram* $\epsilon\alpha\gamma$, *cui similis erit arcus epicycli* $\eta\gamma\theta$ *seu* $\lambda\gamma\mu$. *Subtrahendus hoc loco ab arcu (m[edio] m[otu] Lunae à Sole dupli[cata])* $\lambda\mu\zeta$. *Ut prodeat angulus* $\zeta\gamma\alpha$ *trigoni dati* $\gamma\zeta\alpha$. *Unde reliquus* $\gamma\alpha\zeta$ *angulus, priori* $\beta\gamma\alpha$ *conjunctus adaequabit tandem aequationem orbis Lunae,* $\beta\nu\alpha$, *primario inquirendam.*

Given the mean anomaly of the moon, $\epsilon\beta\gamma$, ($\delta\theta\zeta$ *[sic for* $\delta\gamma\theta$*?]*), there will be given in the triangle $\gamma\beta\alpha$ the equation $\beta\gamma\alpha$ (or $\delta\gamma\eta$), which yields the true anomaly $\epsilon\alpha\gamma$ *[that is,* $\epsilon\beta\gamma - \beta\gamma\alpha = \epsilon\alpha\gamma$*]* to which the arc of the epicycle $\eta\gamma\theta$ or $\lambda\gamma\mu$ is equal. This amount must be subtracted from the arc $\lambda\mu\zeta$ (doubled mean elongation) in order to get the angle $\zeta\gamma\mu$ of the given triangle $\gamma\zeta\alpha$. Whence the remaining angle $\gamma\alpha\zeta$ added to the earlier $\beta\gamma\alpha$ finally yields the equation of the lunar orb, $\beta\nu\alpha$, which was originally sought.

Commentary: *What is really sought is the final true anomaly* $\epsilon\alpha\zeta$, *which follows from the mean anomaly when the final equation* $\beta\nu\alpha$ *is known. Here, as on ff. 198v and 206, the large circle measures the mean*

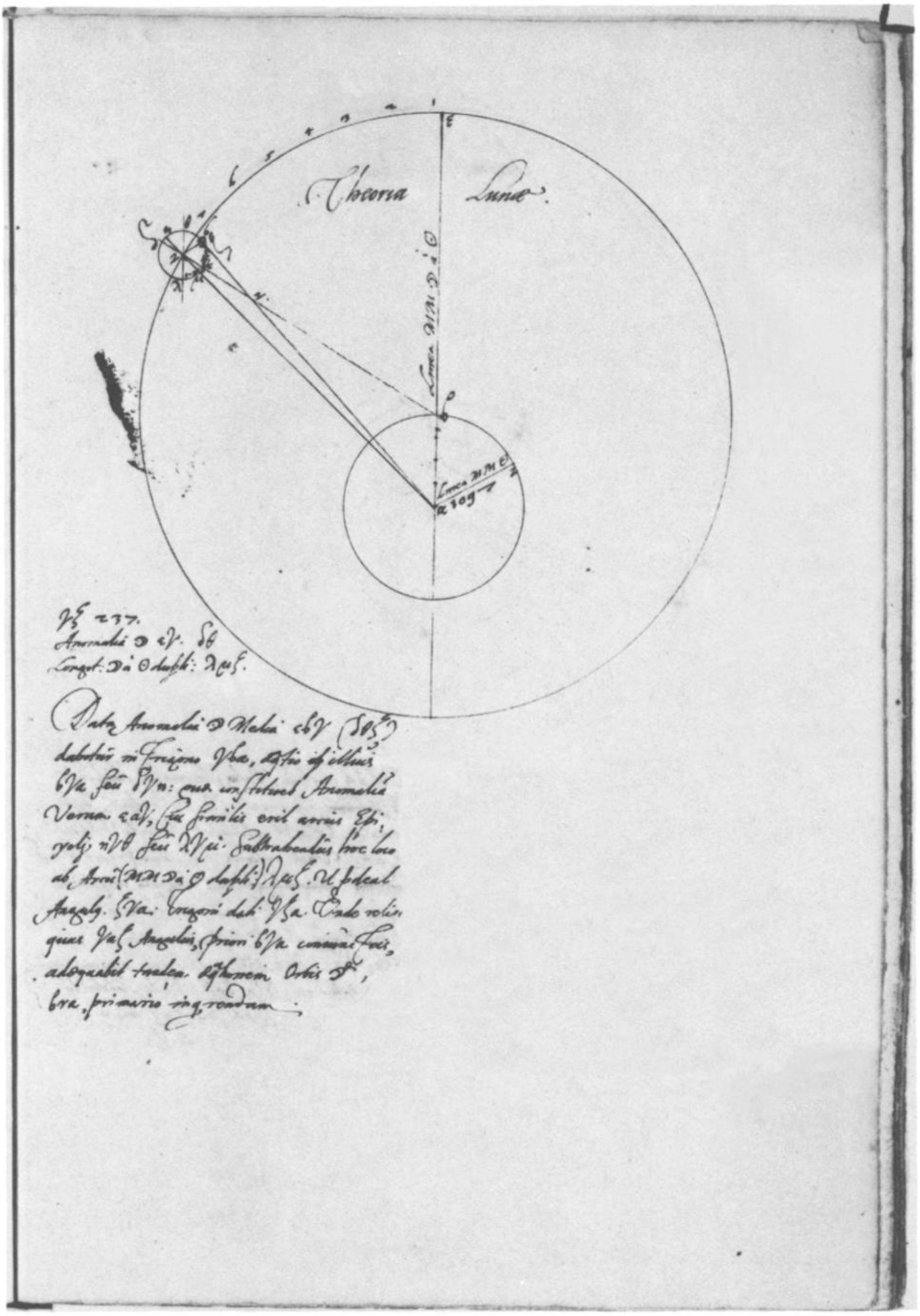


Fig. 26. Vatican f. 202, the eccentrepicyclic lunar theory.

motion, but in this case the moon itself does not move along the circle. As on f. 198v, Wittich chooses his angles so that the vertical is both the line of mean lunar apogee and the line of the mean solar motion, and in the confusion he misidentifies both of his labeled lines.

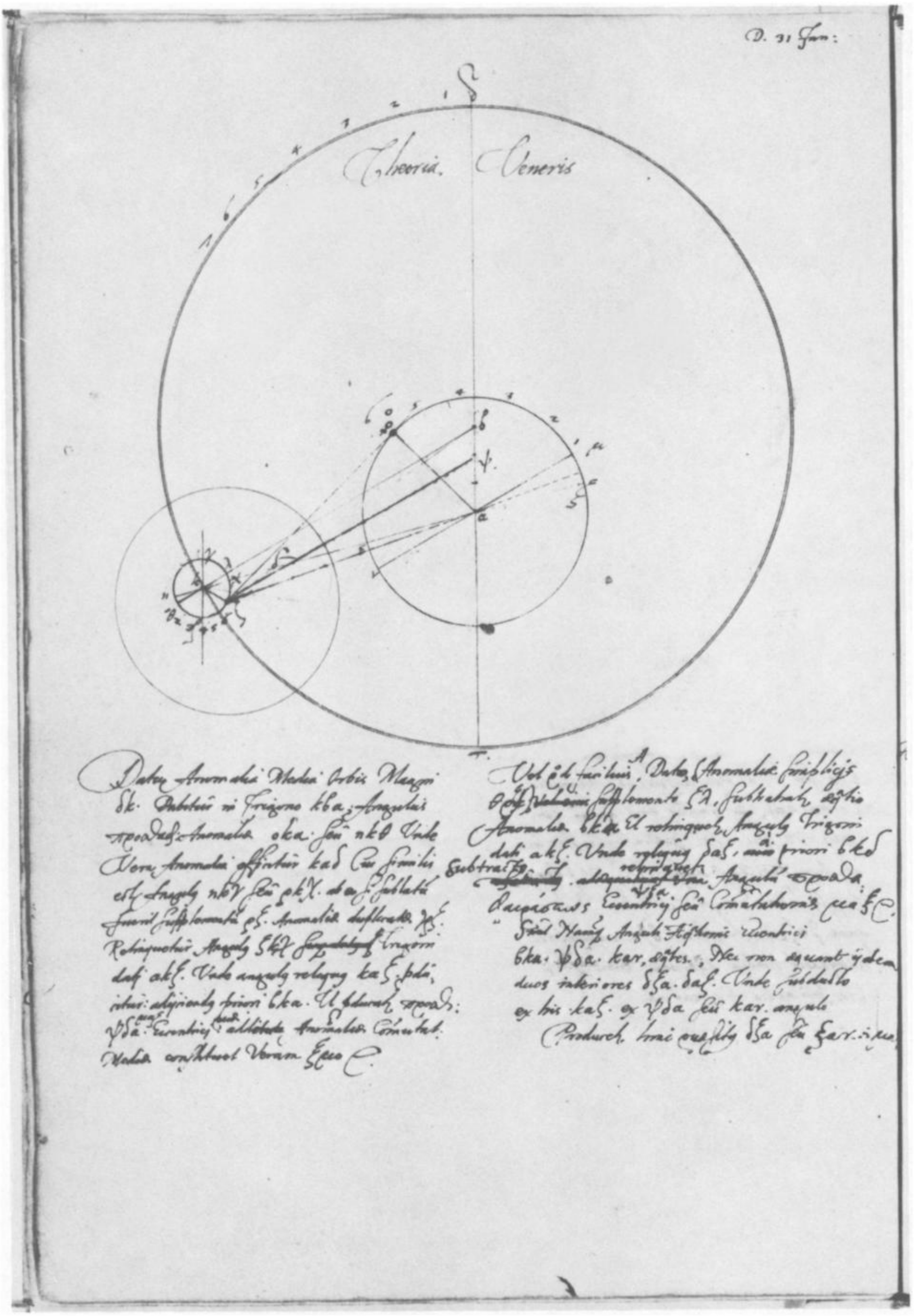


Fig. 27. Vatican f. 202v, an eccentrepicyclic theory of Venus. Note: the epicycle rides on the earth's eccentric, rather than on that of Venus; therefore, this model is not strictly parallel to the previous models of this second mode.

[f. 202v – Theory of Venus]

Theoria Veneris *D[ie] 31 Jan[uarii]*

Data anomalia media orbis magni $\delta\kappa$, dabitur in trigono $\kappa\beta\alpha$ angulus προσθαφ[αιρέσεως] anomaliae $o\kappa\alpha$ [sic for $\beta\kappa\alpha$] seu $\eta\kappa\theta$ unde vera anomalia afficitur $\kappa\alpha\delta$ cui similis est angulus $\eta\kappa\gamma$ seu $\rho\kappa\chi$. [ab?] Si sublatum fuerit supplementum $\rho\zeta$ anomaliae duplicatae $\gamma\rho\zeta$ relinquetur angulus $\zeta\kappa\chi$ ~~sequentxx~~ trigoni dati $\alpha\kappa\zeta$. Unde angulus reliquus $\kappa\alpha\zeta$ producitur adiiciendus priori $\beta\kappa\alpha$. Ut producatur προσθαφ[αίρεσις] $\psi\delta\alpha$. $\mu\alpha\xi$. Eccentrici quae additata anomaliae commutat[ionis] mediae constituet veram $\xi\mu o$ q[uaesitum].

Vel quod facilius, a dato (anomaliae simplicis $\theta\rho\zeta$) ~~vel eius~~ supplemento $\zeta\lambda$, subtrahatur aequatio anomaliae $\beta\kappa\alpha$ et relinquetur angulus trigoni dati $\alpha\kappa\zeta$. Unde reliquus $\delta\alpha\zeta$, à priori $\beta\kappa\delta$ subtractus ~~xxiunctus adaequabunt unà~~ relinquetur angulum προσθαφαιρέσεως eccentrici $\psi\zeta\alpha$ seu commutationis $\mu\alpha\xi$ q[uaesitum]. Sunt namque anguli aequationis eccentrici $\beta\kappa\alpha$. $\psi\delta\alpha$. $\kappa\alpha\nu$ aequales. Nec non aequant quidem duos interiores $\delta\zeta\alpha$. $\delta\alpha\zeta$. Unde subducto ex his $\kappa\alpha\zeta$ ex $\psi\delta\alpha$ seu $\kappa\alpha\nu$ angulo producetur hinc quaesitus $\delta\zeta\alpha$ seu $\xi\alpha\nu$, id est $\mu\alpha\xi$.

Given the mean anomaly of the great orb $\delta\kappa$, there will be given in triangle $\kappa\beta\alpha$ the angle of the equation of the anomaly $\beta\kappa\alpha$ or $\eta\kappa\theta$ from which is established the true anomaly $\kappa\alpha\delta$, to which angle $\eta\kappa\gamma$ or $\rho\kappa\chi$ is equal. If from this latter is taken away the supplement *[the excess over 180°]* $\rho\zeta$ of the doubled anomaly [arc] $\gamma\rho\zeta$, the angle $\zeta\kappa\chi$ of the given triangle $\alpha\kappa\zeta$ is left, whence the remaining angle $\kappa\alpha\zeta$ is found and added to *[actually, subtracted from]* the previous [angle] $\beta\kappa\alpha$ in order to give the equation of the eccentric $\psi\delta\alpha$ *[sic for $\psi\zeta\alpha$]* (or $\mu\alpha\xi$), which, added to the mean anomaly of parallax establishes the sought-for true [anomaly] arc $\xi\mu o$.

Or, in fact more easily, the equation of the anomaly $\beta\kappa\alpha$ is subtracted from the given supplement $\zeta\lambda$ (of the simple anomaly $\theta\rho\zeta$) and the angle of the given triangle $\alpha\kappa\zeta$ is left. From this the remainder $\delta\alpha\zeta$ subtracted from the previous $\beta\kappa\delta$ leaves the sought-for angle of the equation of the eccentric $\psi\zeta\alpha$ or of the equation of parallax $\mu\alpha\xi$. For the angles of the equation of the eccentric $\beta\kappa\alpha$, $\psi\delta\alpha$, and $\kappa\alpha\nu$ are equal, and also they equal [the sum of] the two interior angles $\delta\zeta\alpha$ and $\delta\alpha\zeta$. Whence, subtracting from these, $\kappa\alpha\zeta$ from angle $\psi\delta\alpha$ or $\kappa\alpha\nu$, gives the sought-for $\delta\zeta\alpha$ or $\zeta\alpha\nu$, that is, $\mu\alpha\xi$.

Commentary: *This arrangement (as well as the one that follows for Mercury) is very strange, since it requires the earth to move in a small epicycle to produce the planet's equation of center, and the exercise itself is rather confusing.*

Since $\beta\psi$ equals $\kappa\zeta$ and also $\kappa\beta\psi$ equals $\beta\kappa\zeta$ (the supplement of the mean anomaly), there is an isosceles trapezoid in which the lines

$\beta\kappa$ and $\zeta\psi$ are parallel, as is line $\mu\alpha\nu$. Wittich uses this relationship in the second paragraph. Wittich's intention here appears somewhat limited: to find the equation of the eccentric or of the commutation, which corrects the mean anomaly of parallax, arc μo. As defined on f. 199, the required angle here is $\mu\alpha\xi$, but in the first paragraph he seems to have originally placed ξ erroneously on the extension of $\kappa\alpha$, which was later partly erased so that thereafter ξ is on the extension of line $\zeta\alpha$. Hence, in the first paragraph Wittich intended to say, "thus the equation $\psi\zeta\alpha$ is produced" (as he does in the second paragraph) instead of "the equation $\psi\delta\alpha$." Note also that Wittich has used the letter δ twice, once at the top of the diagram when he refers to the mean anomaly $\delta\kappa$, and again between the small circles for the equation being sought, $\delta\zeta\alpha$.

[f. 203 – Theory of Mercury]

Theoria Mercurii

Aequationi anomaliae orbis ~~aequationi~~ $\beta\kappa\alpha$ datae,
~~subtract~~ addatur ~~ab~~ anomalia epicycli similis
$\epsilon\gamma\zeta$. Ut prodeatur angulus in trigono hinc dato
$\zeta\kappa\alpha$. Unde tertius $\zeta\alpha\kappa$ cum priori $\theta\kappa\alpha$
conjunctus adaequabunt unà, angulum
προσθαφαιρέσεως eccentrici $\beta\theta\alpha$ & com-
mutationis $\xi\mu$, qui datam commutationem
mediam ~~arcus~~ $\mu\beta\nu$ constituet veram $\xi\beta\nu$ quaesitam.
Amoto, (in hac theoria), epicyclio λo, poterit assumta
libratio planetae (per diametram
$o\lambda\pi$,) transferri in centrum deferentis ~~alteram~~
sub homocentrum $\phi\alpha$. Ut cap[ut] 32
lib[er] V à Copernico traditum constat.
Verùm minus certè ut praemissa; haec eadem calculo expedivi
poterit sicut alibi demonstratam à me reperies.

To the given equation of the anomaly of the orb, [angle] $\beta\kappa\alpha$, is added the anomaly of the epicycle equal to [arc] $\epsilon\gamma\zeta$ [$\zeta\kappa\epsilon$] such that angle $\zeta\kappa\alpha$ is produced in the given triangle. Whence the third [angle] $\zeta\alpha\kappa$ joined with the first $\theta\kappa\alpha$ will together equal the angle of the equation of the eccentric $\beta\theta\alpha$ and of the parallax $\xi\mu$—which, given the mean [arc] of the parallax $\mu\beta\nu$ [on the inner dotted circle], will establish the sought-for true arc $\xi\beta\nu$.

In this theory, when epicyclet λo is moved, the assumed libration of the planet along the diameter $o\lambda\pi$ could be transferred to the center of the deferent under the homocentric $\phi\alpha$—as is established in the treatment by Copernicus in Book V, chapter 32. Although less certain than the foregoing, this can be explained by the same calculation just as you

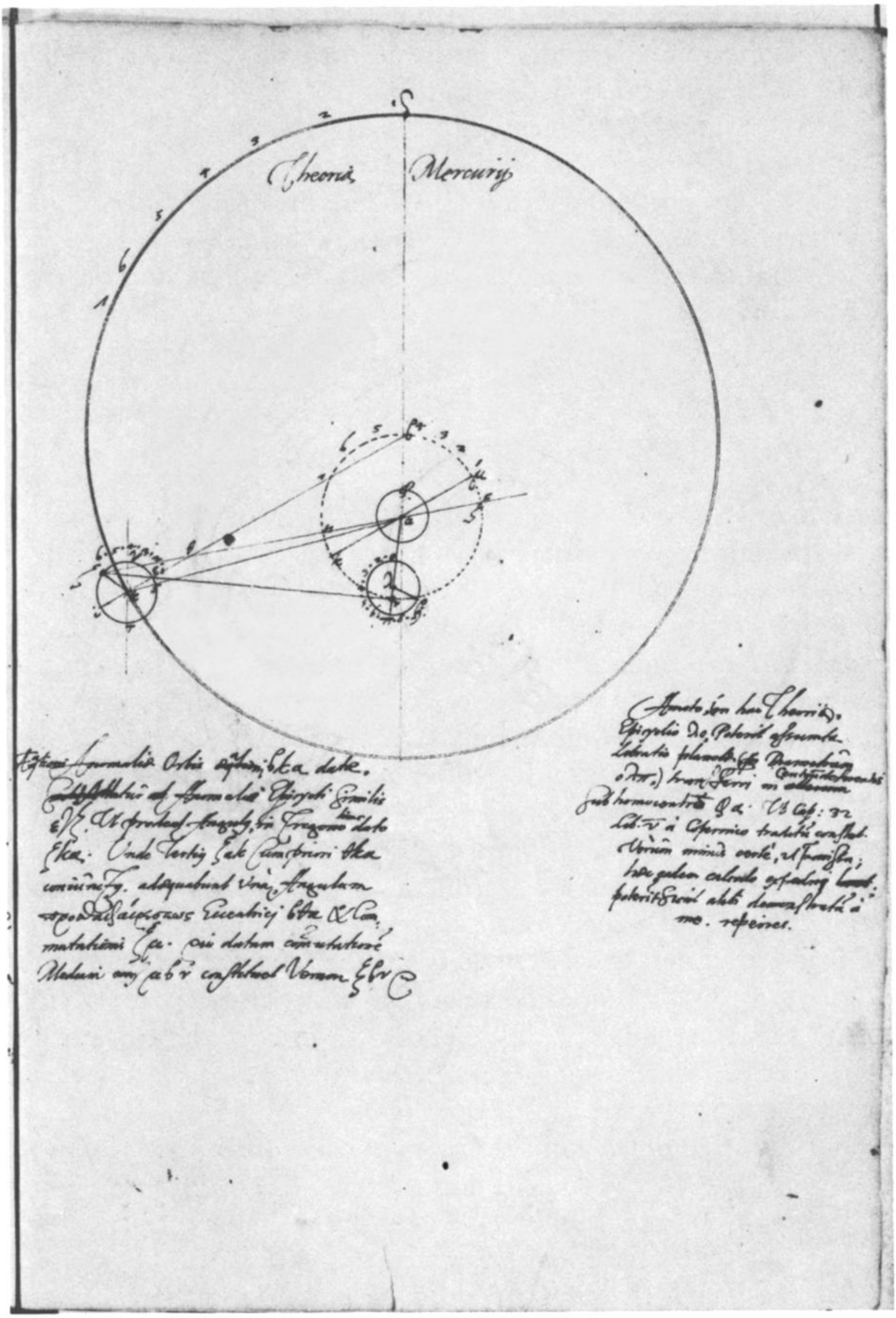


Fig. 28. Vatican f. 203, the eccentreccentrepicyclic theory of Mercury.

Commentary: *[f. 203] The standard theory for Mercury given by Copernicus in* De revolutionibus *V,25 is diagrammed by Wittich on f. 199v; the strange one here is the first of Wittich's variations, although he has noticed that Copernicus has yet another arrangement in V,32. Copernicus' standard and alternative Mercury models have been discussed in detail by Noel Swerdlow, "Copernicus's Four Models of Mercury,"* Studia Copernicana *13 (1975), pp. 141–55.*

In this arrangement, the librational circlet that controls the size of Mercury's circle is the lower one at λ. The mean anomaly is $\delta\beta\kappa$, and $\mu\alpha\kappa'$ is parallel to the line of mean anomaly (where κ' is the second κ, found on the dotted circular orbit of Mercury). The central circlet of f. 199v is here transferred to the great orb, and the innermost circlet appears to be irrelevant.

[ff. 203v–204v – Solar Theory]

Commentary: *At this point Wittich has completed a second set of planetary diagrams, beginning on f. 201 with the superior planets. He spent Wednesday, 30 January 1578, making a pair of neatly labeled diagrams for the solar and lunar theories (ff. 201v, 202), and he has begun Thursday with a comparable set for Venus and Mercury (ff. 202v, 203). It is quite possible that he now begins searching for a unified mechanism—which seems to find its fulfillment in a remark on f. 206, that the same kinds of tables can handle all the different cases. The three unlabeled diagrams that follow seem to involve the solar theory: in each case a large circle is double-lined (his standard designation for the* orbis magnus*), and the double epicycles are within a typical Copernican framework. The first form of the Copernican solar theory employs an eccentrically placed interior circlet; the eccentricity can be represented by a somewhat larger circle, as Wittich does here, but the placement of the circlet upon it is always on the mean apsidal line, conventionally shown as a vertical. The two circles, always maintaining their vertical orientation, can be moved to the outer circle, as in Copernicus' second form. The invariable vertical orientation of the double circles in these three diagrams confirms that they do refer to the solar theory.*

Although these diagrams stand here without text, three closely related diagrams with commentary are found within the book proper on ff. 94–95. On pages 114–15 we reproduce and transcribe the most relevant one.

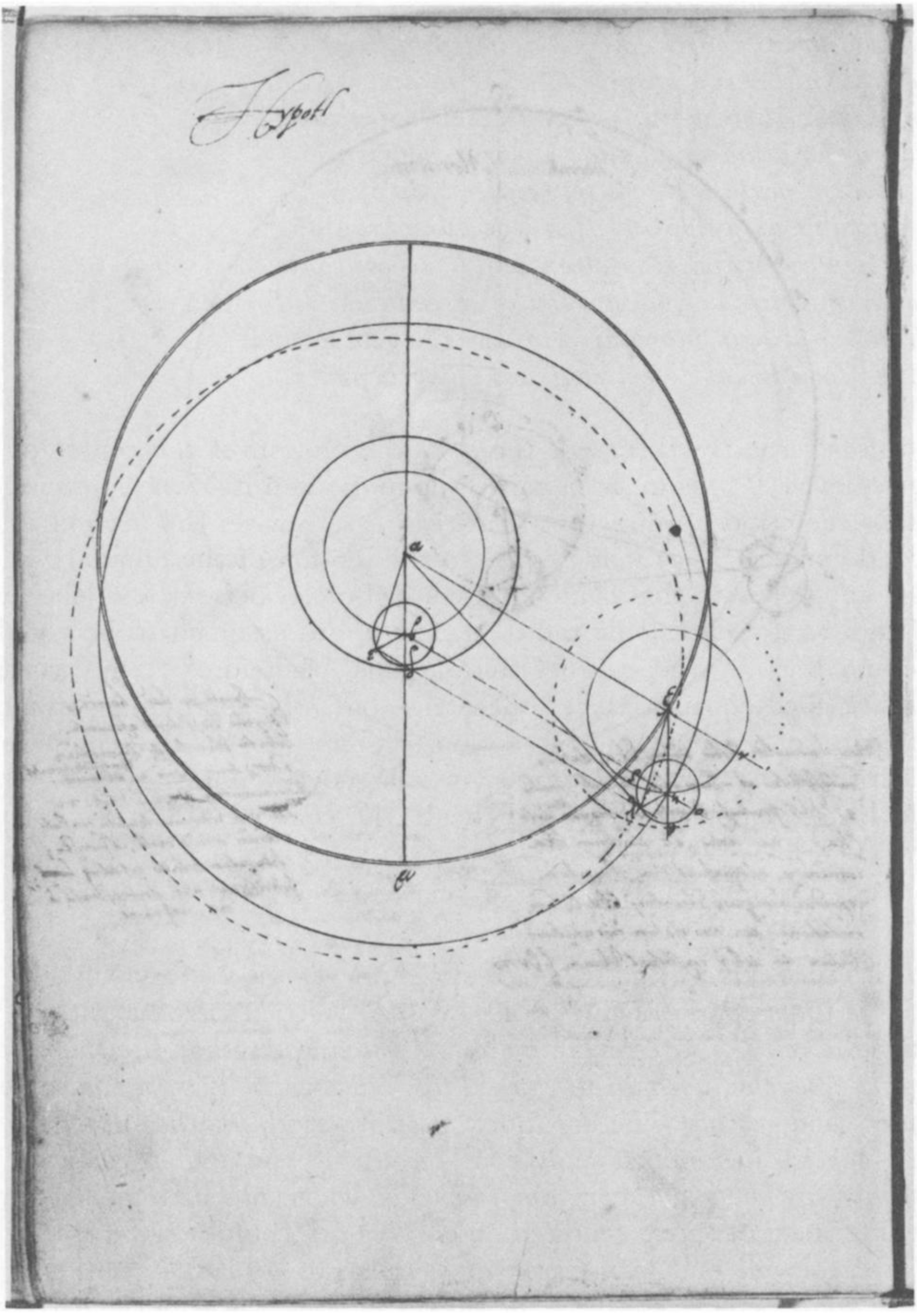


Fig. 29. Vatican f. 203v, a trial for a double-epicycle solar theory.

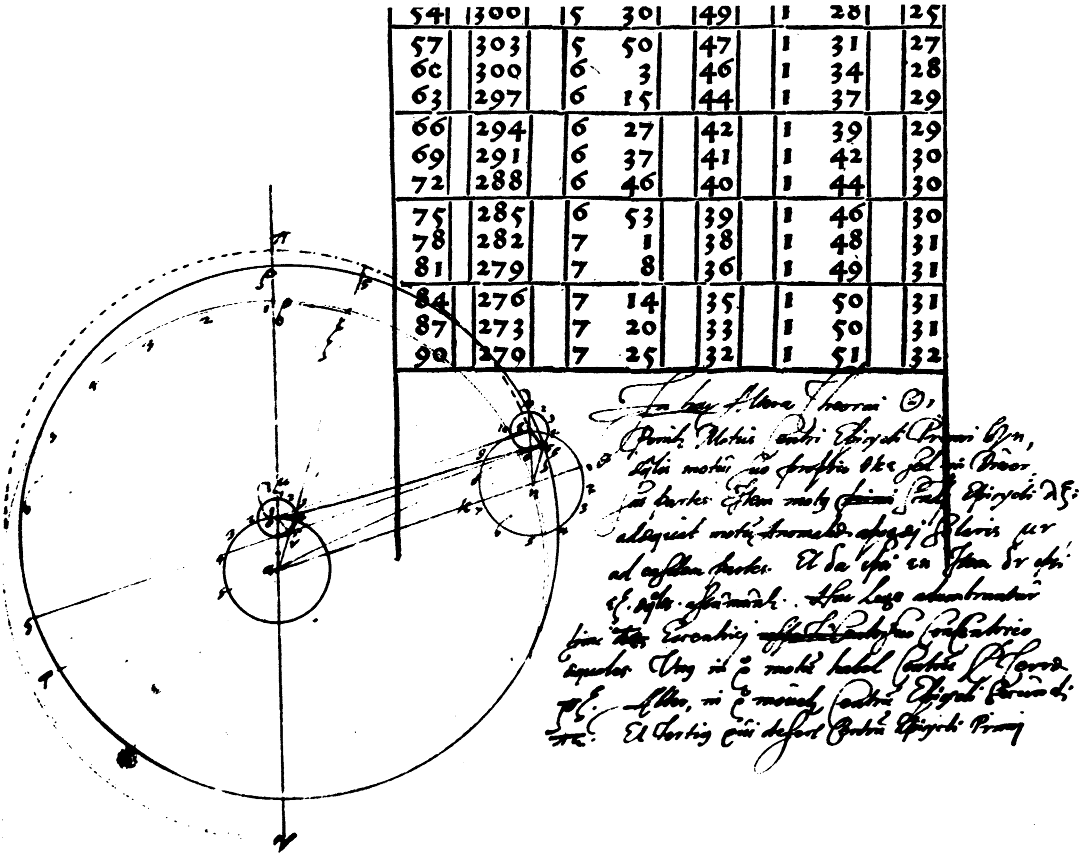
[f. 94v – Solar Theory]

In hac altera theoria Solis,
ponitur motus centri epicycli primi $\beta\gamma\eta$,
aequalis motui suo proprio $\theta\kappa\epsilon$ sed in diver-
sas partes. Item motus ~~primi~~ secundi epicycli $\lambda\zeta$
adaequat motum anomaliae apogaei solaris $\mu\nu$
ad easdem partes. Et $\delta\alpha$ ipsi $\epsilon\eta$ item $\delta\nu$ ipsi
$\epsilon\zeta$ aequales assumuntur. Hac lege adumbrantur
hinc tres eccentrici ~~respectum centr~~ suo concentrico
aequales. Unus in quo motum habet centrum ~~ϵ~~ Terrae
$\rho\zeta$. Alter, in quo movetur centrum epicycli secundi
$\pi\epsilon$. Et tertius qui defert centrum epicycli primi.

In this alternative theory of the sun, the motion of the center of the first epicycle $\beta\gamma\eta$ is made equal to the motion on its own [epicycle] $\theta\kappa\epsilon$ but in the opposite direction *[clockwise]*. Likewise, the motion of the second epicycle $\lambda\zeta$ is made equal to the motion of the anomaly of the solar apogee $\mu\nu$ in that same direction *[also clockwise]*. And [the radii] $\delta\alpha$ and $\epsilon\eta$ as well as [the radii] $\delta\nu$ and $\epsilon\zeta$ are assumed to be equal to one another. By this rule [of the motions], therefore, three eccentrics are described equal to their concentric—one *[the solid circle]* in which the center of the earth has its motion, $\rho\zeta$; another *[the dashed circle]* in which the center of the second epicycle is moved on arc $\pi\epsilon$; and a third *[the light doubled circle]* which bears the center of the first epicycle [$\beta\gamma\eta$].

[returning to f. 204]

Commentary: *The most enigmatic, and yet most suggestive, in the series is the second drawing (f. 204), where Wittich introduces three additional circles of intermediate size. Wittich knew that the same basic double-epicyclic mechanism worked for Venus as well as for the superior planets and, with a different function and period, for the sun. Suppose that Wittich has momentarily considered that the double epicycles belong not to the solar theory but to Venus, whose orb he represents with the intermediate circle centered on ϵ. This orb could now be treated as a third epicycle and transferred to λ, thus riding on the small epicycle of the double epicycles. If, at the same time, the places of the earth and sun are switched between α and ζ, the move to a systemic geoheliocentric arrangement would have started. Wittich does not yet make such a claim, although some of the elements have begun to fall into place. Instead, he turns next, on the following day, to the second mode for the superior planets.*



54	300	5	30	49	1	28	25
57	303	5	50	47	1	31	27
60	300	6	3	46	1	34	28
63	297	6	15	44	1	37	29
66	294	6	27	42	1	39	29
69	291	6	37	41	1	42	30
72	288	6	46	40	1	44	30
75	285	6	53	39	1	46	30
78	282	7	1	38	1	48	31
81	279	7	8	36	1	49	31
84	276	7	14	35	1	50	31
87	273	7	20	33	1	50	31
90	279	7	25	32	1	51	32

Fig. 30. Vatican f. 94v, the double-epicycle solar theory.

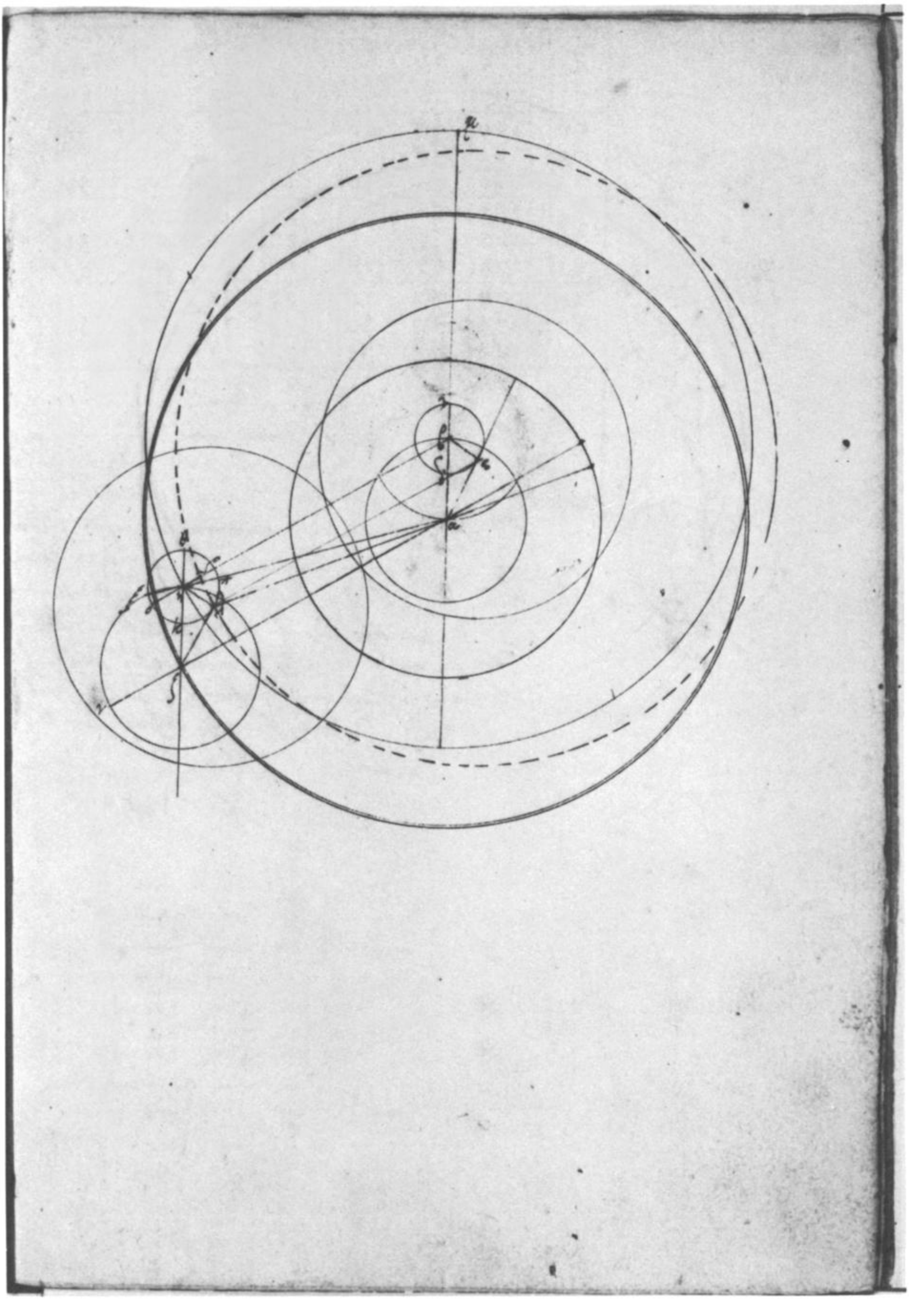


Fig. 31. Vatican f. 204, another trial for a double-epicycle solar theory.

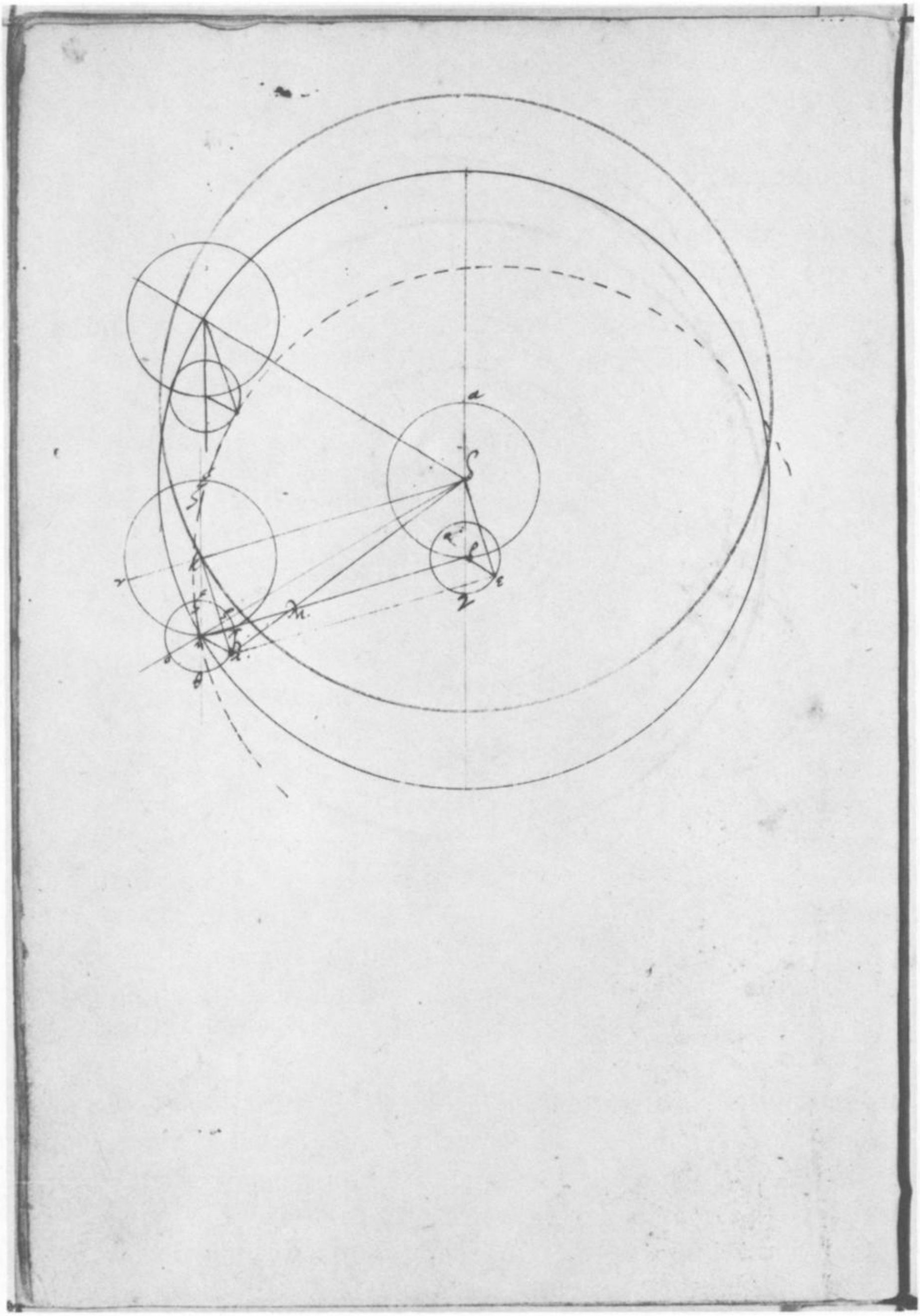


Fig. 32. Vatican f. 204v, a third trial for a double-epicycle solar theory.

[f. 205 – Theory of the Three Superior Planets]

Alia Trium Superiorum Theoria, Ex Cap. 20 Lib. 3 D. Copernici derivata.
D[ie] 1 Feb[ruarii] a[nn]o [15]78

Another theory of the three superior planets, derived from Book III, chapter 20 of Master Copernicus. 1 February 1578

[above the diagram]

Si epicyclum εη repositum fuerit in β, habebitur
alia Theoria pro Saturno, Jove, Marte.

If the epicycle εη were placed at β, there would be yet another theory for Saturn, Jupiter, and Mars.

[on the diagram]

Linea m[edii] m[otus]	Line of mean motion
Linea v[eri] m[otus]	Line of true motion
Linea app[arenti] m[otus]	Line of apparent motion

[below the diagram]

Anomalia duplicata	ζοη	Doubled anomaly
Προσθαφαίρ[εσις] centri	εβη	Equation of the center
Anomalia simplex	δε	Simple anomaly
Anomalia vera	δβη	True anomaly
Προσθαφ[αίρεσις] I epicycli ~~seu~~	βαη	Equation of the first epicycle
seu commutationis	καθ	or of the parallax
Commutatio m[edia]	θο	Mean parallax
vera	κο	True [parallax]
Προσθαφαίρ[εσις] com[mut]at[ionis]		Equation of commutation
seu παραλλάξ[εως]	αηο	or of the parallax

Commentary: *This diagram begins Wittich's third series, now according to the second, or epicycle-on-epicycle, mode, as listed for the superior planets in the Liège commentary and as numbered by Reinhold in the margins of Copernicus' solar theory on III,20. That Wittich refers to this latter source (that is, a solar theory even though he is here concerned with the superior planets) is undoubtedly due to the convenient double-epicycle solar diagram in Book III of* De revolutionibus, *whereas the planetary discussion in Book V does not actually illustrate this construction. Note that in this mode the main circles are all concentric, and the arrangement is, in Reinhold's word, "homocentrepicyclic"; the orbital eccentricities are in each case carried by the larger epicycle.*

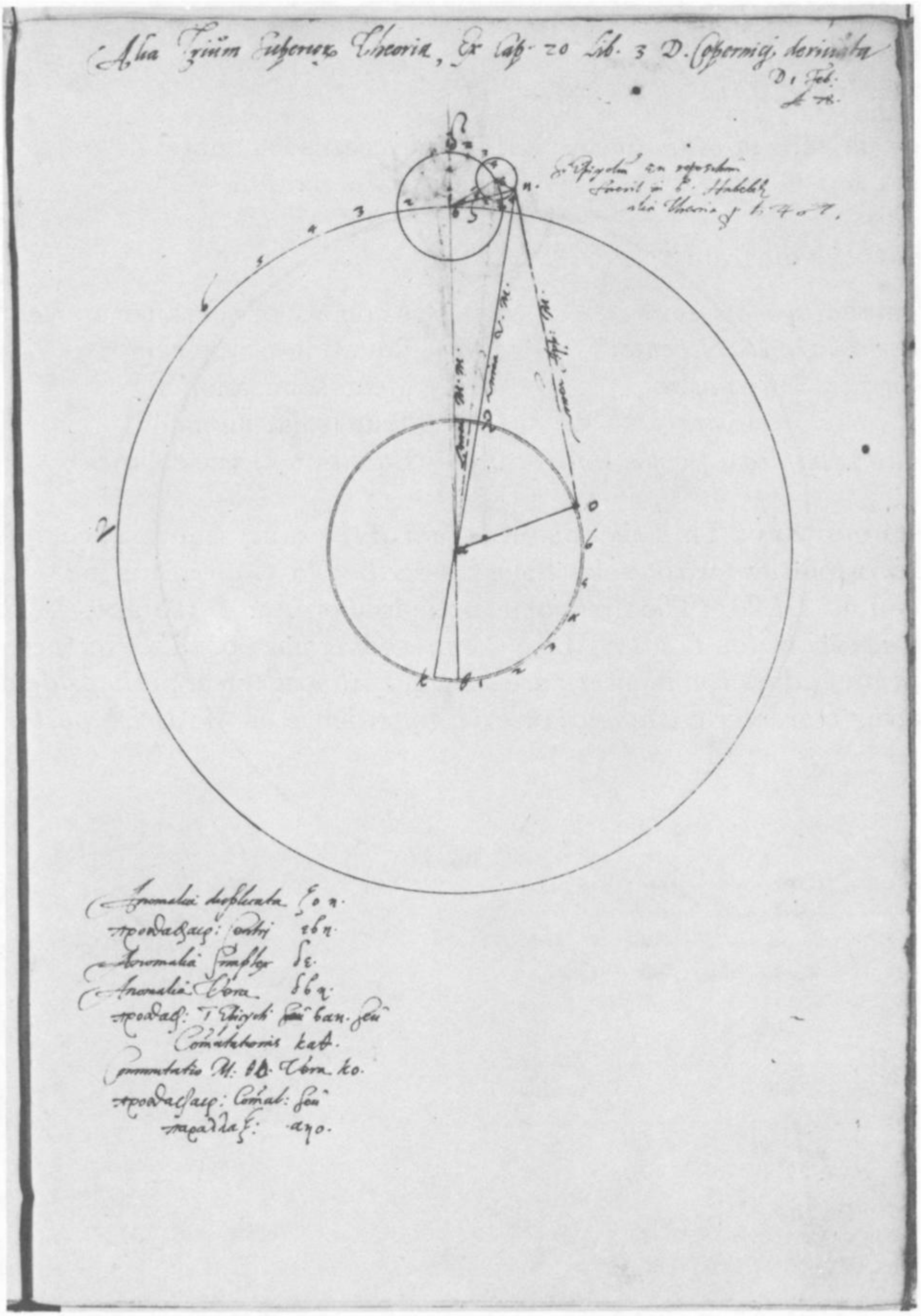


Fig. 33. Vatican f. 205, double-epicycle theory of the superior planets.

[f. 205v – Solar Theory]

Theoria Solis

[on the diagram]

Linea m[edii] m[otus] Solis	Line of mean solar motion
Linea veri motus	Line of true motion

[below the diagram]

Anomalia apogaei solaris	$\zeta\eta$	Anomaly of the solar apogee
Προσθαφαίρ[εσις] centri	$\epsilon\beta\eta$	Equation of the center
Anomalia Solis media	$\delta\epsilon$	Mean solar anomaly
vera	$\delta\beta\eta$	True [solar anomaly]
Προσθαφαίρ[εσις] orbis Solis	$\beta\alpha\eta$	Equation of the solar orb

Commentary: *This, the solar diagram of the third sequence, completes the possibilities for the solar theory described by Copernicus in* De revolutionibus *III,20. (The first solar mode is shown on f. 198 and the third mode is shown on f. 201v.) Like the preceding page of this sequence, the diagram and its commentary are succinct, almost terse, perhaps demonstrating a greater confidence or even impatience on Wittich's part.*

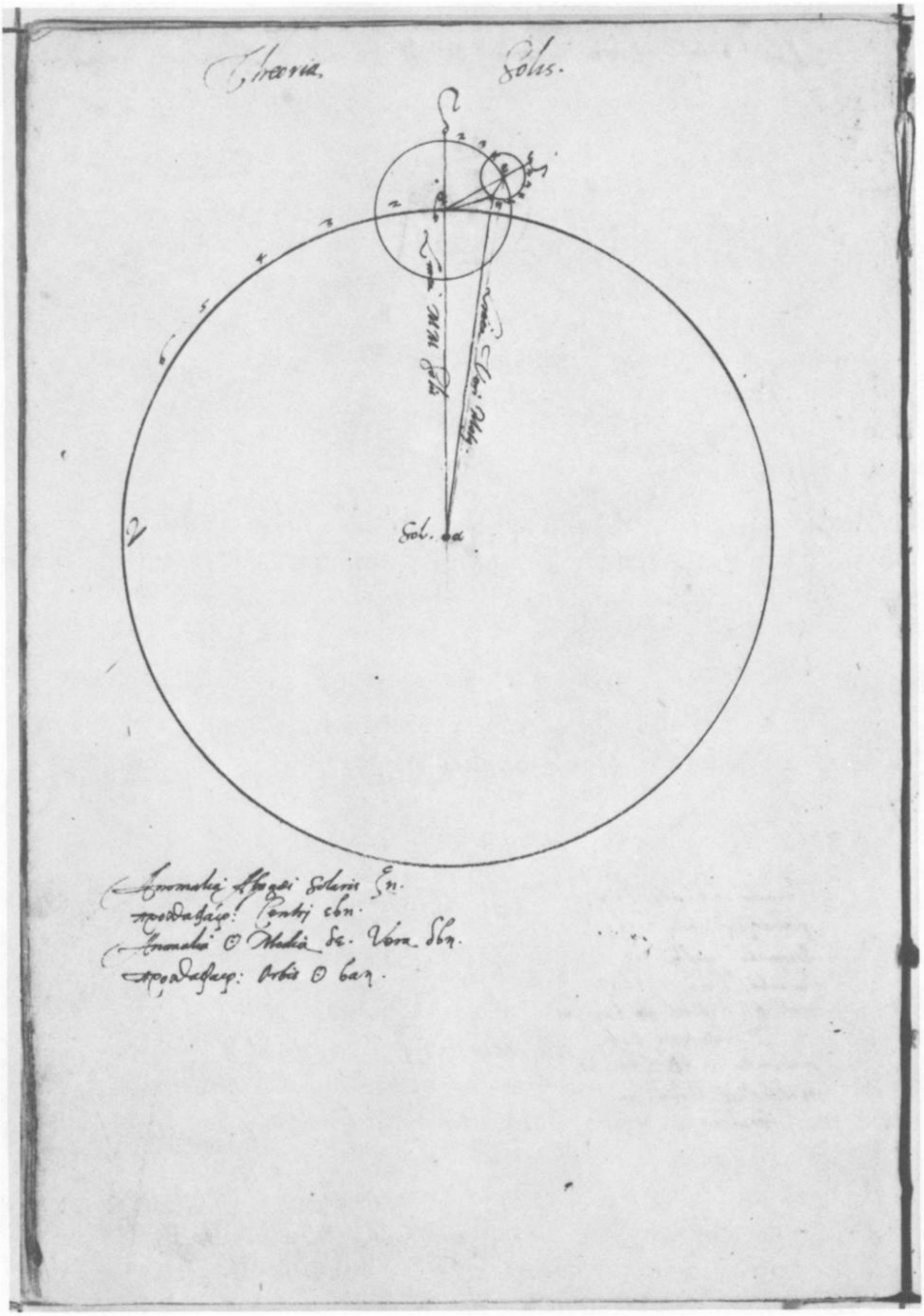

Theoria.
Solis.
Sol. a
2
3
4
5
6
Anomalia Absidis Solaris Ξn.
προσθαφαίρεσις: Centri cbn.
Anomalia ☉ Media de. Vera dbn.
προσθαφαίρεσις: Orbis ☉ ban.

Fig. 34. Vatican f. 205v, the double-epicycle solar theory.

[f. 206 – Lunar Theory]

[on the diagram]

Theoria Lunae quam assumsit Copernicus.
The lunar theory as Copernicus assumed.

Linea m[edii] m[otus] Lunae à Sole	Line of the mean lunar elongation
Linea v[eri] m[otus] Lunae à Sole	Line of the true lunar elongation

[at the upper right corner]

Ex haec hypothesi patet,
ut reliquorum planetarum tabulae
aequationum, excessuum & scrup[ulorum]
propor[tionalium] possint, compendio
singulari, exarari.
Vide supra fol[io] 113.

From this arrangement it appears that tables of equations, excesses, and proportional minutes for the remaining planets may be written down in a single compendium. See folio 113 above.

[below the diagram]

Anomalia Lunae media	*δε*	Mean lunar anomaly, arc *δε*
M[edia] m[otus] Lunae à Sole duplicatus	*ζη*	Mean doubled elongation
Προσθαφαίρ[εσις] II epicycli	*εβη*	Equation of the second epicycle
Anomalia Lunae vera	*δβη*	True lunar anomaly
Προσθαφαίρ[εσις] I epicycli	*βαη*	Equation of the first epicycle

NB. Angulus προσθαφαιρέσεως I epicycli. Ut hac in theoria, ita in aliis similib[us] exarari atq[ue] in tabulas aequationum transferri, ~~poterit sive praemissa aequatione primi epicycli poterit sed~~ tali etiam quodam compendio poterit. Data anomalia media δβε, dabitur trigonus βεα, & latus eius εα, cum angulo βαε, et reliquo de duob[us] rectis βεα; quo subtracto ab angulo ζεη relinquitur trigonus duorum laterum cum angulo comprehenso ηεα. Unde angulus reliquus εαη cum priori βαε conjunctus, constituet ut supra aequationem I epicycli, primariò quaesitam.

NB: The angle of the equation of the first epicycle. In this theory, as in other similar ones, it will be possible to write down a certain special

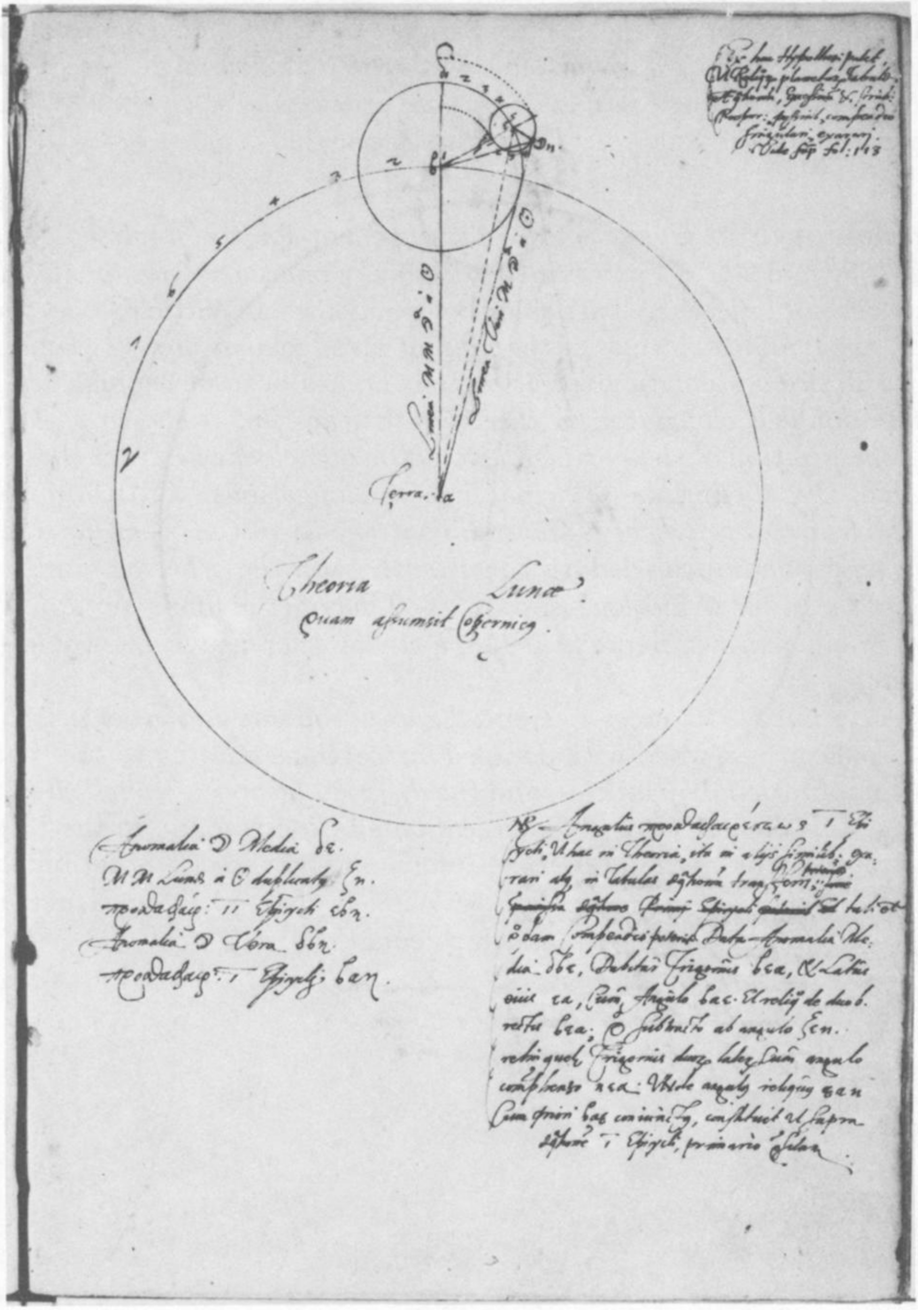


Fig. 35. Vatican f. 206, the Copernican double-epicycle lunar theory.

Given the mean anomaly $\delta\beta\epsilon$, the triangle $\beta\epsilon\alpha$ and its side $\epsilon\alpha$, together with the angle $\beta\alpha\epsilon$ are given, and the remainder from two right [angles] is $\beta\epsilon\alpha$; subtracting this from angle $\zeta\epsilon\eta$ *[the doubled elongation]*, there is left the triangle of two sides with the included angle $\eta\epsilon\alpha$. From this the remaining angle $\epsilon\alpha\eta$ added to the previous $\beta\alpha\epsilon$, as above, yields the equation of the first epicycle originally sought.

Commentary: *In giving a third arrangement for the lunar epicycles (cf. ff. 198v and 202), Wittich finally displays Copernicus' own plan. The delay does not reflect any particular independence on Wittich's part, but rather, the double epicycles of the present arrangement now fit properly into the entire systematic exposition that he has been developing.*

The doubled elongation in the epicyclet, arc $\beta\eta$, is shown as 120°; hence the position of the mean sun would be 60° clockwise from the vertical line. By labeling the principal lines as elongations, Wittich implies that the frame of reference is the sun, contrary to all the other diagrams in the series; had he labeled $\alpha\beta$ consistently with the other diagrams as "Line of mean lunar motion" and $\alpha\eta$ as "Line of true lunar motion," as shown in our redrawn figure at f. 198, a stellar reference frame would be suggested.

Concerning f. 113, cross-referenced above, the side and lower margins of that page are crowded with detailed instructions relating to the tabulated computational quantities, and the diagram has been embellished to resemble this one. A virtually identical annotation is found in the Liège De revolutionibus *on ff. 112v–13. Unfortunately, these annotations do not give enough details to know how Wittich planned to construct his "single compendium" for the planetary equations.*

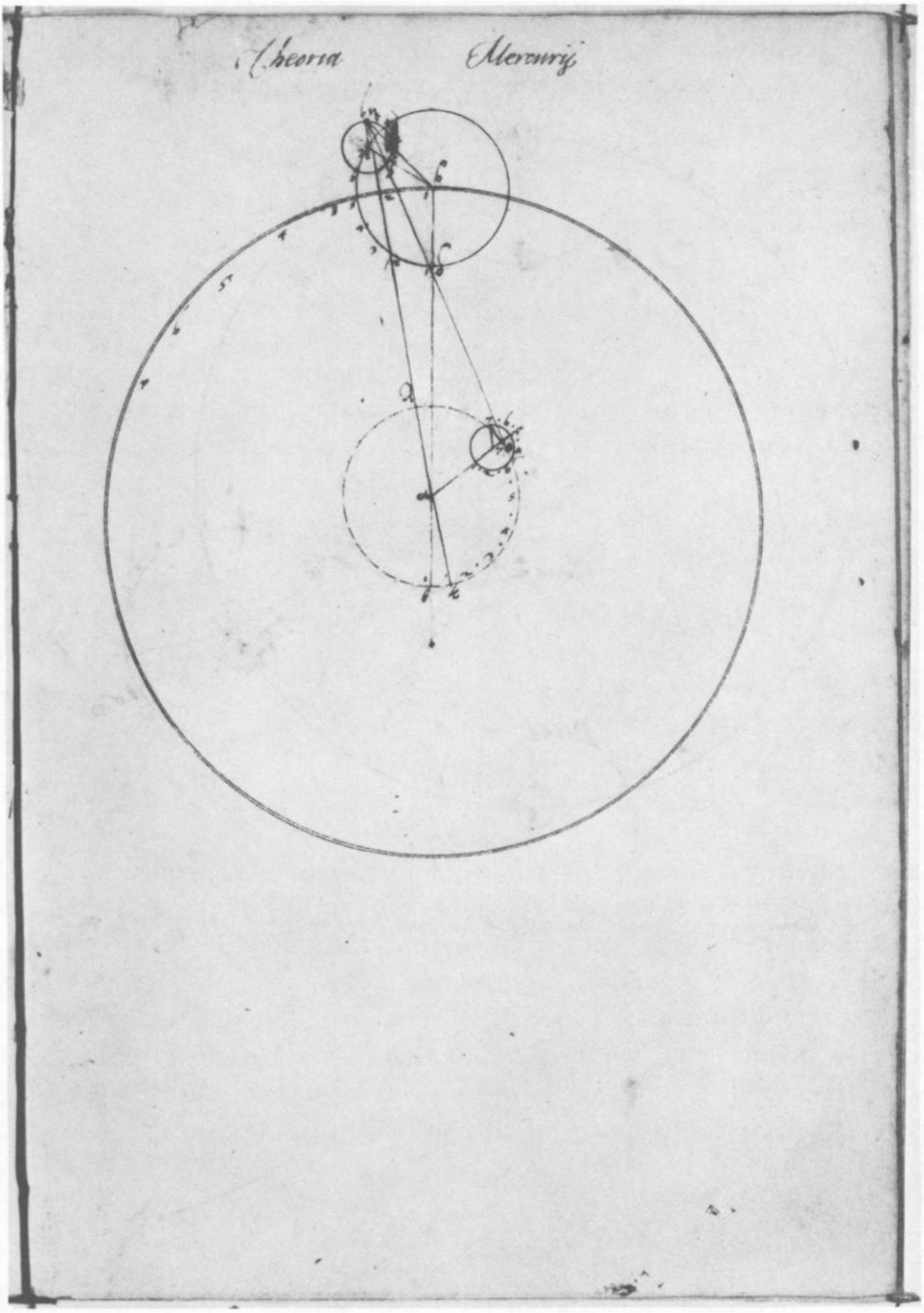


Fig. 36. Vatican f. 207, a double-epicycle trial for Mercury. (We deliberately place this folio out of sequence so that the transcribed text of f. 206v can face the picture of the manuscript.)

[f. 206v – Theory of Venus] *Theoria Veneris*

[on the diagram]

Linea motus medii	Line of mean motion
L[inea] m[otus] veri	Line of true motion
L[inea] m[otus] apparentis	Line of true motion

[below the diagram]

Anomalia media	δε.ζη	Mean anomaly
Προσθαφαίρ[εσις] II epicycli seu centri	εβη	Equation of the second epicycle or of the center.
Anomalia vera	ηβδ	True anomaly
Προσθαφαίρ[εσις] I epicycli	ηαβ	Equation of the first epicycle
seu commutationis	θακ	or of the parallax
Anomalia commutationis media	θλκο	Mean anomaly of the parallax
vera	κλο	True [anomaly of the parallax]
Προσθαφαίρ[εσις] orbis seu παραλλάξεως	οηα	Equation of the orb or of the parallax

[within the diagram]

Alia constituetur theoria si epicyclum ζε repositum fuerit in locum Veneris.

Another theory will be formed if the epicycle ζε is moved to the position of Venus.

Commentary: *The double-epicycle arrangement provides a natural transformation for the model of Venus, but notice that the double epicycle rides on the earth's eccentric rather than Venus'. The problem is similar to that of Venus in the previous series, on f. 202v. The side note concerning an alternative theory, by changing the order of the epicycle and its epicyclet, parallels the remark on f. 205 for the superior planets, and the ductus (i.e., the flow of ink and writing) suggests that both notes were written at the same time, after the main diagrams were in place.*

[f. 207 – Theory of Mercury] *Theoria Mercurii*

Commentary: *The arrangement of Mercury according to the second mode is more problematic for Wittich than for the previous models, and he clearly does not succeed in the goal of making the Mercurian orbit concentric with the great orb, a difficulty already just encountered with Venus. The task of moving Mercury's eccentricity to the larger epicycle seems to have aborted, which may account for the lack of any text. On*

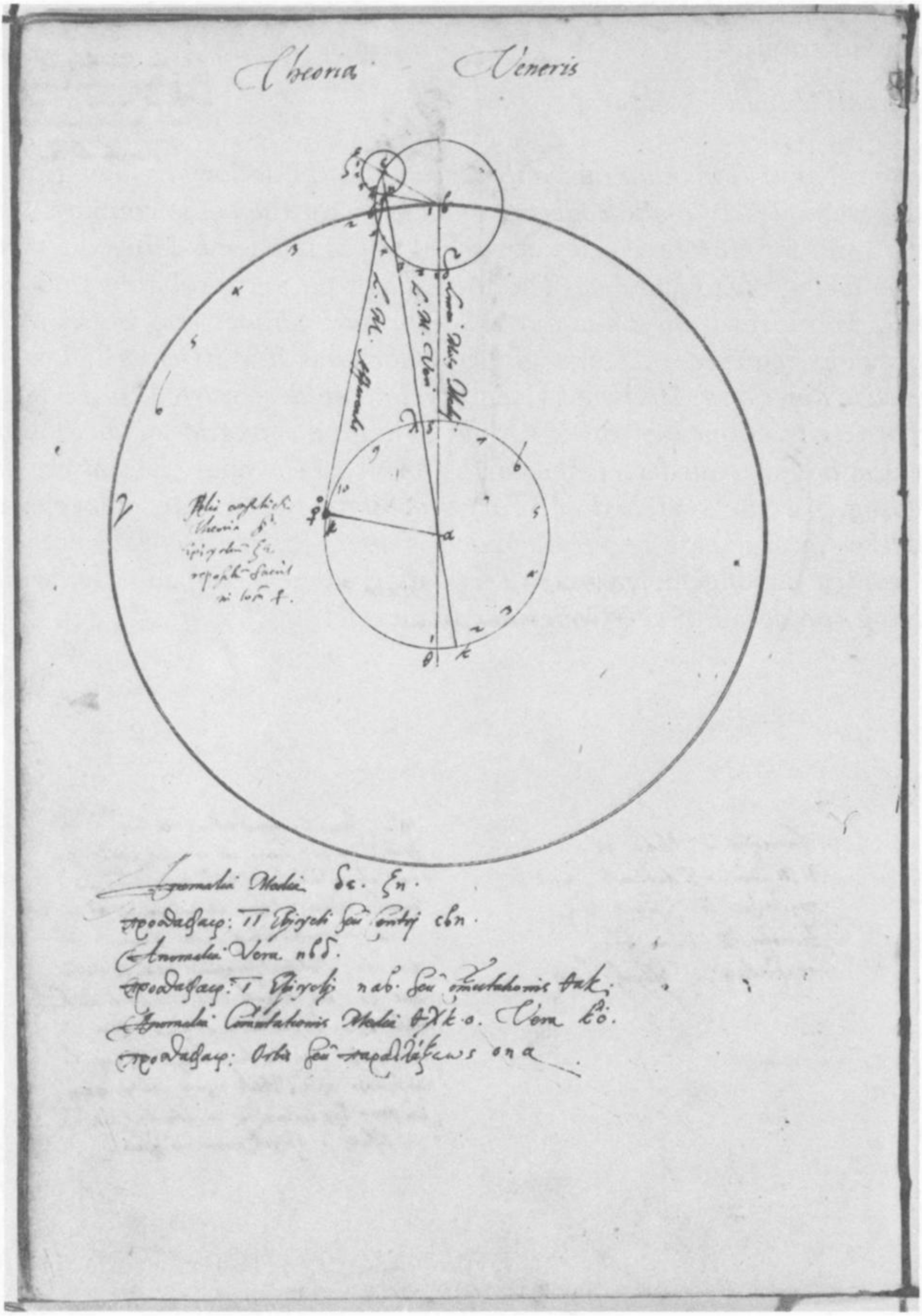

Theoria Veneris
L. M. Apparentis
L. M. Veri
Linea Motus Medij
Anomalia Media δε. ζn.
Prosthaphaer: II Epicycli seu Centri cbn.
Anomalia Vera nbδ.
Prosthaphaer: I Epicycli nab· seu Commutationis bak.
Anomalia Commutationis Mediæ bλk·o. Vera kô.
Prosthaphaer: Orbis seu παραλλάξεως ona

Fig. 37. Vatican f. 206v, the double-epicycle theory of Venus.

the other hand, it might have stimulated his thinking about further arrangements, such as the geocentric scheme on the following page.

[f. 207v – Theory of the Superior Planets – Saturn, Jupiter, and Mars]

[on the diagram]

[Saturnus], [Iuppiter], [Mars]

Commentary: *This diagram and the one on the following facing page (f. 208) were clearly made together—not only do the same compass settings prevail for the three sizes of circles, but this page is labeled Prima and the facing one Secundus. The next diagram, and probably this one as well, were drawn on Thursday, 13 February, almost two weeks after the previous sequence. At first glance it looks as if Wittich is following the earlier hint (on f. 205) that the epicyclet could be moved to the large concentric circle, but instead of simply switching the order of the double epicycles, he has transferred the earth's orbit to the edge, just as on the preceding page he switched Mercury's orbit to become an epicycle, in both cases producing a neo-Ptolemaic scheme. Wittich has thus created a geocentric arrangement, with Terra marked near the middle, while retaining the detail of the Copernican epicyclet.*

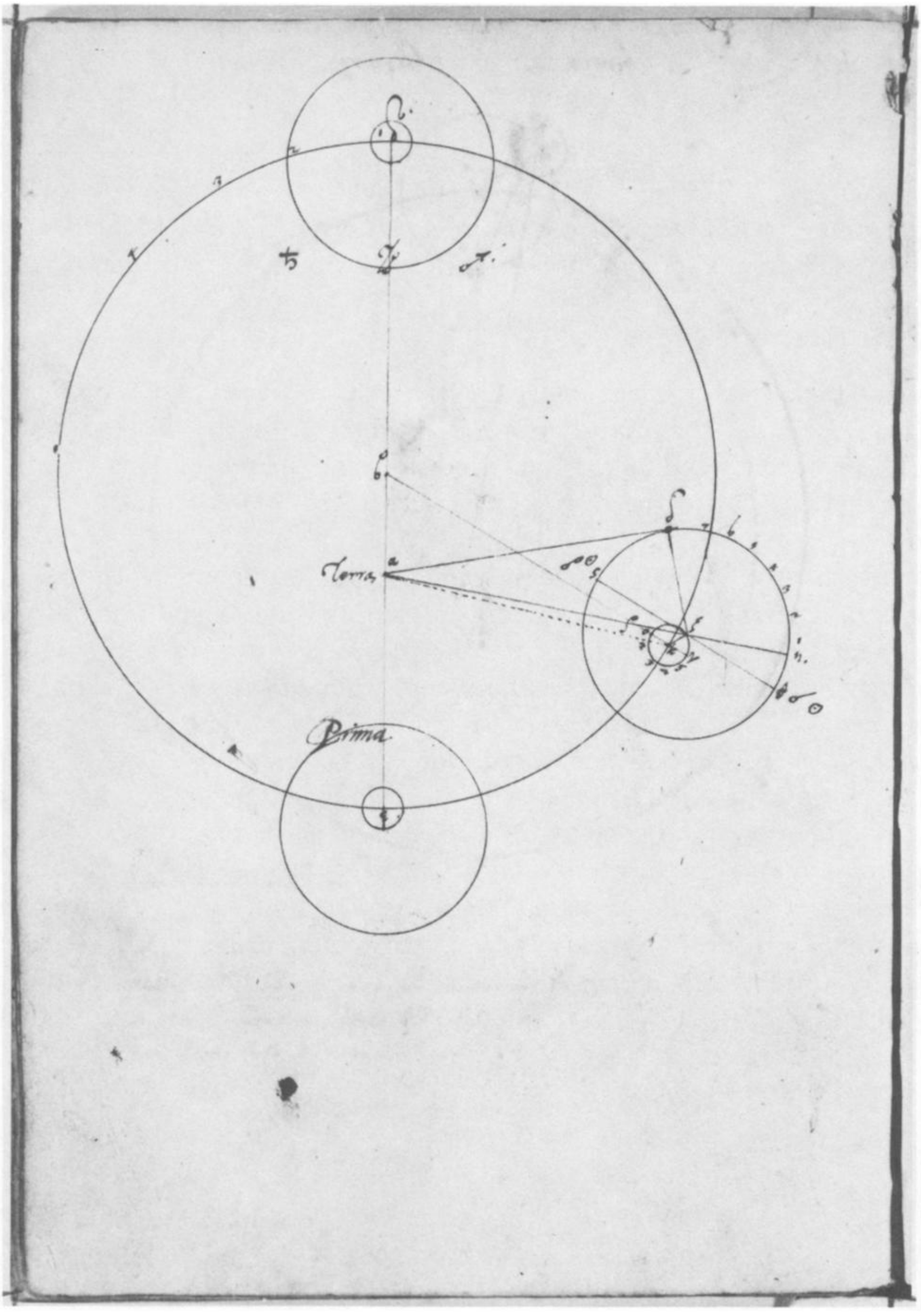


Fig. 38. Vatican f. 207v, first geocentric theory of the superior planets.

[f. 208 – Theory of the Three Superior Planets]

Theoria Trium Superiorum ad Terrae Immobilitatem accommodata.
The theory of the three superior planets accommodated
to the immobility of the earth.

[above the diagram to the right]

Haec nova hypotheseon ratio à me reperta anno 78 d[ie] 13 Feb[ruarii].
This new system of hypotheses occurred to me on 13 February 1578.

[on the diagram]

οκ Semidiameter epicycli, adaequat hoc loco, in tribus superiorib[us] semidiametrum orbis magni
οκ The epicycle's radius for the three superior planets in this case is made equal to the radius of the great orb.

Commentary: *Wittich clearly considers his discovery of the geocentric arrangement significant, worth recording with a specific date and comment. The lapse of time since the previous drawings and the documentary note suggest that the plan is not premeditated. Somehow, after the interval, Wittich returns to the problem with a new perspective. Terra is clearly marked near the middle.*

Apart from his remark that the epicycle is made equal in size to the earth's great orb, the specific details are not in themselves particularly noteworthy, and there are few additional comments. Having taken the geocentric step on the previous page, Wittich now brings the epicyclet back to the center, analogous to the arrangement with which he started on f. 197v. The scheme shows clearly the true apsidal line, as did the initial one on f. 197v.

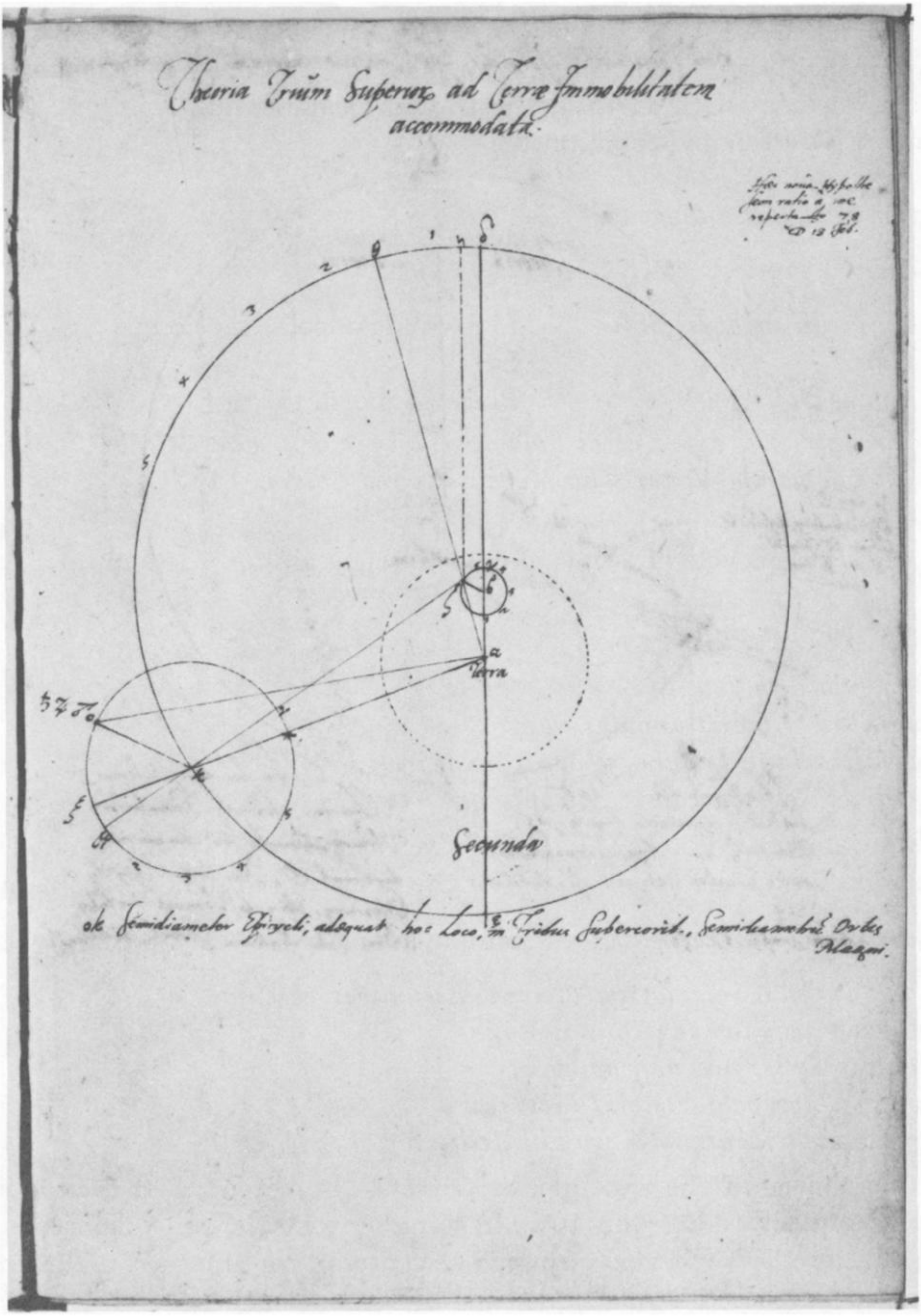

Theoria Triū̃ Superior. ad Terræ Immobilitatem accommodata.
a
Terra
b
Secunda
ok Semidiameter Epicycli; adequat hoc Loco, in Tribus Superiorib., Semidiametrū Orbis Magni.

Fig. 39. Vatican f. 208, second geocentric theory of the superior planets.

[f. 208v – Theory of Venus]

[caption across the opening ff. 208v–209]

Quomodo Conveniat Copernicus, In Theoria duorum Inferiorum, Cum Hypothesi Immobilitatis Terrae. Ex Ptolemaei Sententia.

How in the theory of the two inferior planets Copernicus may be brought into agreement with the hypothesis of the earth's immobility in accordance with Ptolemy's opinion.

[on or beside the diagram]

Theoria Veneris.

Linea medii m[otus] Solis		Line of mean solar motion
δ	*Terra*	Earth
γ	*Locus Solis*	Place of the sun

$\beta\gamma$ *Eccentricus, deferens et Solem.*
Et epicyclum Veneris ac Mercurii circa Solem.

Eccentric carrying both the sun
and the epicycle of Venus and of Mercury around the sun.

[below the diagram]

Ab angulo $\alpha\gamma\delta$ *seu* $\lambda\rho\delta$
subtractus si fuerit angulus $\gamma\delta\epsilon$*:*
relinquitur hinc angulus προσθαφαιρέσεως
eccentrici $\lambda\epsilon\delta$ *seu commutationis* $\eta\epsilon\kappa$*.*

If from angle $\alpha\gamma\delta$ or $\lambda\rho\delta$, angle $\gamma\delta\epsilon$ were subtracted, then the angle of the equation of the eccentric $\lambda\epsilon\delta$ or the angle of parallax $\eta\epsilon\kappa$ remains.

Anom[alia] simplex $\beta\gamma$. $\zeta\epsilon$ Simple anomaly

In hoc duorum inferiorum theoria, assumitur eccentricus
utriusque aequalis seu communiones
deferenti Solis, nec non epicyclus
Mercurii, epicyclo Veneris inclusus,
(circa Solis γ *centrum), simul intelligitur.*

In this theory of the two inferior planets, the eccentric of each of the two is assumed to be equal to or in common with the sun's deferent—as indeed Mercury's epicycle (around the center of the sun γ) is understood to be encompassed at the same time by Venus' epicycle.

Commentary: *The caption crosses the opening of the two folios, indicating that both diagrams belong together, and in fact they show the geocentric arrangements of Venus and Mercury analogous to the "Prima" version of the superior planets on f. 207v. Wittich makes clear that the epicycles of both planets enclose the sun, that is, like the Capellan*

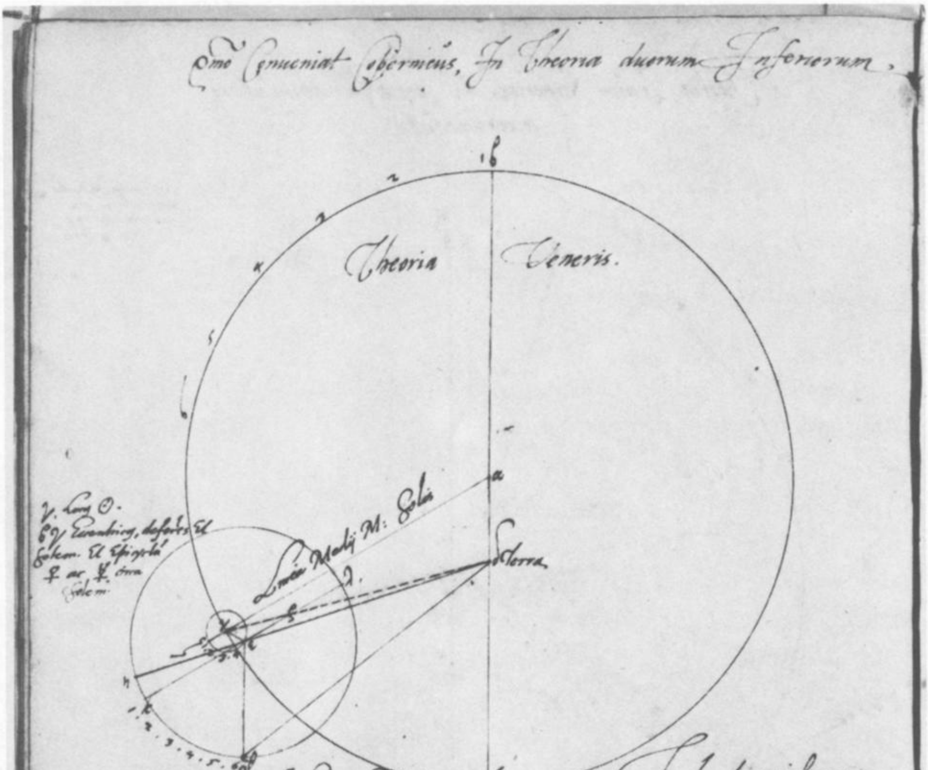


Fig. 40. Vatican f. 208v, the geocentric theory of Venus.

scheme he has sketched on f. 8v of this same volume, or, indeed, as he is about to diagram on f. 210v. But since Mercury and Venus have different eccentricities and apsidal directions, the line $\alpha\delta$ cannot be the same for both planets and the sun (although all these lines will be parallel).

[f. 209 – Theory of Mercury]

D[ie] 14 Feb[ruarii]
14 February

[on or beside the diagram]

Theoria Mercurii

Linea medii m[otus] Solis	Line of mean solar motion
δ *Terra*	Earth
γ *Locus Solis*	Place of the sun
Anom[alia] simplex $\beta\xi\gamma$ *[seu]* $\rho\nu\epsilon$.	Simple anomaly.

Angulus $\alpha\gamma\delta$ *additus ipsi*
$\epsilon\delta\gamma$*, constituet angulum aequationis*
eccentrici $\alpha\rho\delta$ *seu commutationis* $\eta\epsilon\kappa$.

Angle $\alpha\gamma\delta$ added to $\epsilon\delta\gamma$ will establish the angle of the equation of the eccentric $\alpha\rho\delta$ or of the parallax $\eta\epsilon\kappa$.

Commentary: *On this opening, Wittich completes his sequence by showing Venus and Mercury analogous to the "Secundus" version of the superior planets of f. 208. The mean anomaly of 240° is shown on the large eccentric and in the epicyclet that is carried by it. The doubled anomaly of 480° or 120° is exhibited in the auxiliary librational epicyclet, which controls the size of Mercury's circle. As usual, Wittich represents the variable-sized orbital circle with a broken line.*

[f. 209v – Another Theory of Venus]

Altera Veneris

Commentary: *Wittich shows with dotted circles two other possible placements of the epicyclet for Venus in the geocentric form. These are shown on the lower diagram and on the previous opening. Here is a guide to the folios with the various arrangements:*

Heliocentric	*Superior*	*Venus*	*Mercury*
eccentric–on–eccentric (third mode)	*197v*	*199*	*199v*
epicycle–on–eccentric (first mode)	*201*	*202v*	*203*
epicycle–on–epicycle (second mode)	*205*	*206v*	*207*
Geocentric			
eccentric–on–eccentric	*208*	*209v*	*210*
epicycle–on–eccentric	*207v*	*208v*	*209*

The eccentric–on–eccentric mode uses a small eccentrically placed circlet near the center of the orb to control the position of the large eccentric cicrle. The epicycle–on–epicycle mode is the one we have generally called the double–epicycle arrangement.

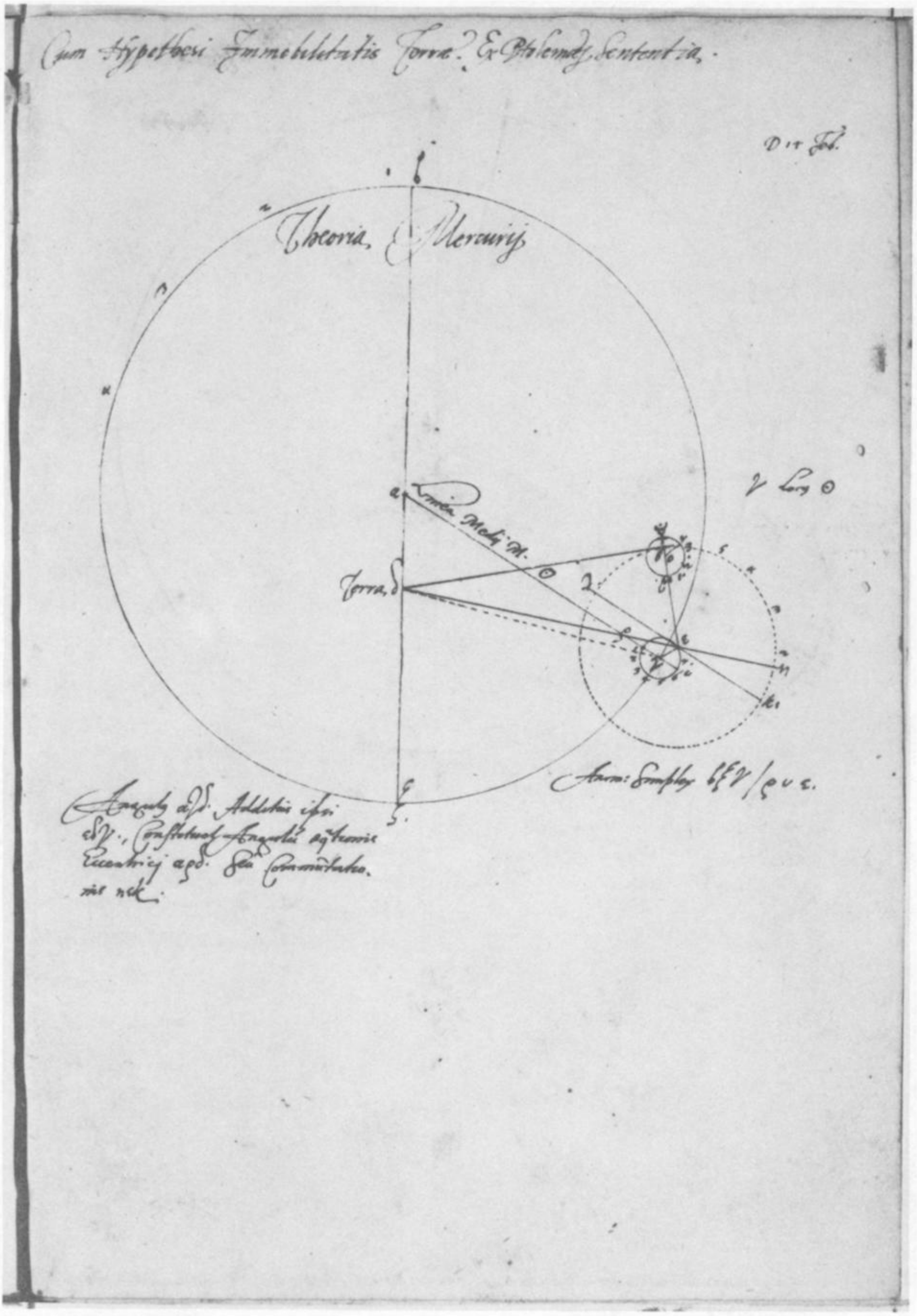

Cum Hypothesi Immobilitatis Terrae. Ex Ptolemaei sententia.
Theoria Mercurij
Linea Medij ☉.
Terra d
☿ Locus ☉
Anom: Simplex b e ☿ / g v e.
Angulus a d b. Additus ipsi e d ☿., Constituet Angulum aequationis Eccentrici a g d. seu Commutationis n e k.
a
b
c
g
k
n

Fig. 41. Vatican f. 209, the geocentric theory of Mercury.

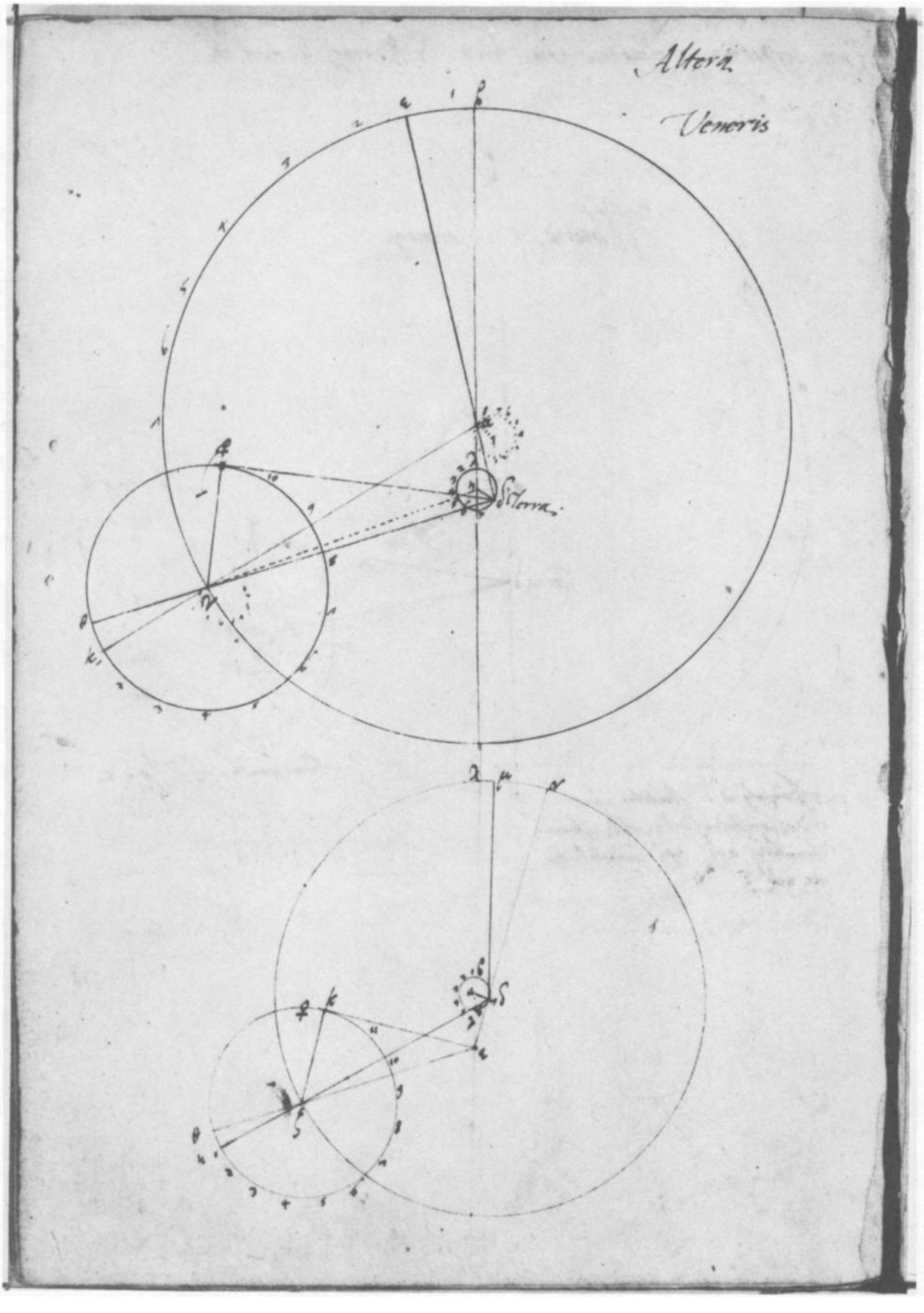


Fig. 42. Vatican f. 209v, another geocentric theory of Venus.

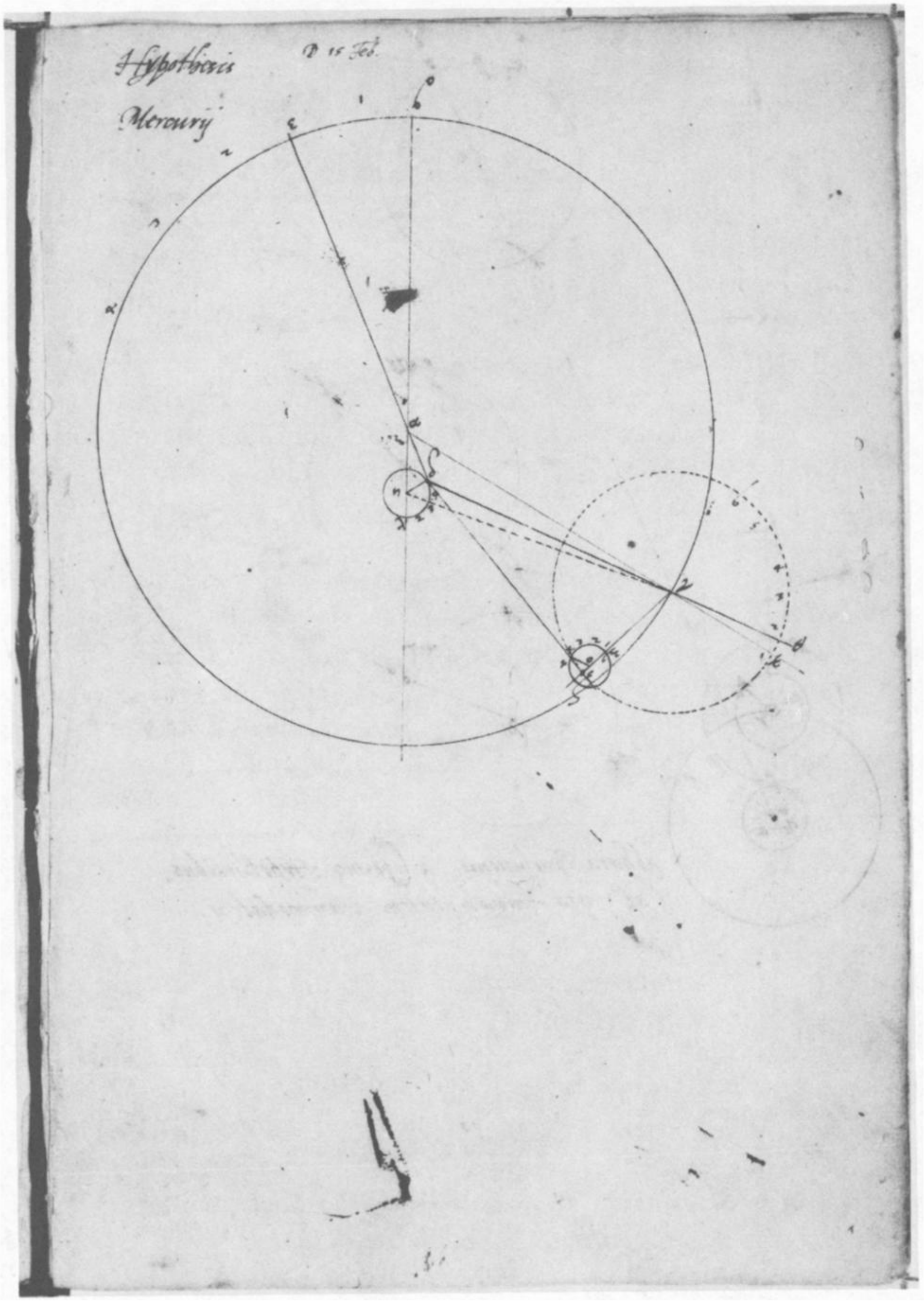


Fig. 43. Vatican f. 210, another geocentric theory of Mercury.

[f. 210 – Theory of Mercury]

Hypothesis Mercurii *D[ie] 15 Feb[ruarii]*
15 February

[f. 210v – The Combined Hypotheses and Sphere]

D[ie] 17 Feb[ruarii]
17 February

[below the diagram]

Sphaera Revolutionum, ex Copernici Hypothesibus,
ad Terrae Immobilitatem accommodata.
The Sphere of Revolutions from the Copernican Hypotheses
accommodated to the Immobility of the Earth.

Commentary: *The title of this diagram, The Sphere of Revolutions, suggests that Wittich has placed before us a mathematician's theatre of the heavens. His Sphere, in the singular, contains the space within which the planets revolve. The entire title could very well serve as a description for all that has gone before, or for an extended commentary on, and reinterpretation of,* De revolutionibus *itself.*

In this final synthesis of the series, Wittich has placed Terra, the earth, firmly at the pivot. Around it circles the moon and Sol, the sun, carrying Mercury and Venus in a Capellan pattern. The epicycles for the superior planets are identical in size to each other and to the great circle now holding the sun itself. The uniform sizing of the epicycles for the superior planets has clearly carried over from the previous days' work, but he has not attempted to scale the deferents themselves. Had he done so, keeping the epicycles the same, the Martian deferent would have shrunk so that the intersection of the Martian epicycle and the solar deferent would have been immediately apparent, as described at the beginning of Section III of our text. (With the deferent of the sun as one unit, the deferent of Mars must be 1.5 units and its epicycle one unit, the epicycle clearly crossing back over the solar deferent by half a unit.) Instead, Wittich has carefully drawn the increments in the radii of the planetary deferents to match the size of the solar deferent; a small mark on the ordinate between the epicycle of Venus and the deferent of Mars reveals that he measured off the diameter of the solar deferent and added to it the radius of the Venus epicycle in order to obtain the radius of the Martian deferent. By so doing, he made certain that none of the epicycles could intersect, but at the expense of representing the sizes of the deferents incorrectly. There is simply no evidence in this long series of diagrams that Wittich considered them to represent actual physical constructions, except for this solitary hint: here he has drawn the circles to prevent any intersection. It seems entirely reasonable to infer that Wittich drew these circles within his Sphere, his unified system, with an eye to solid spheres.

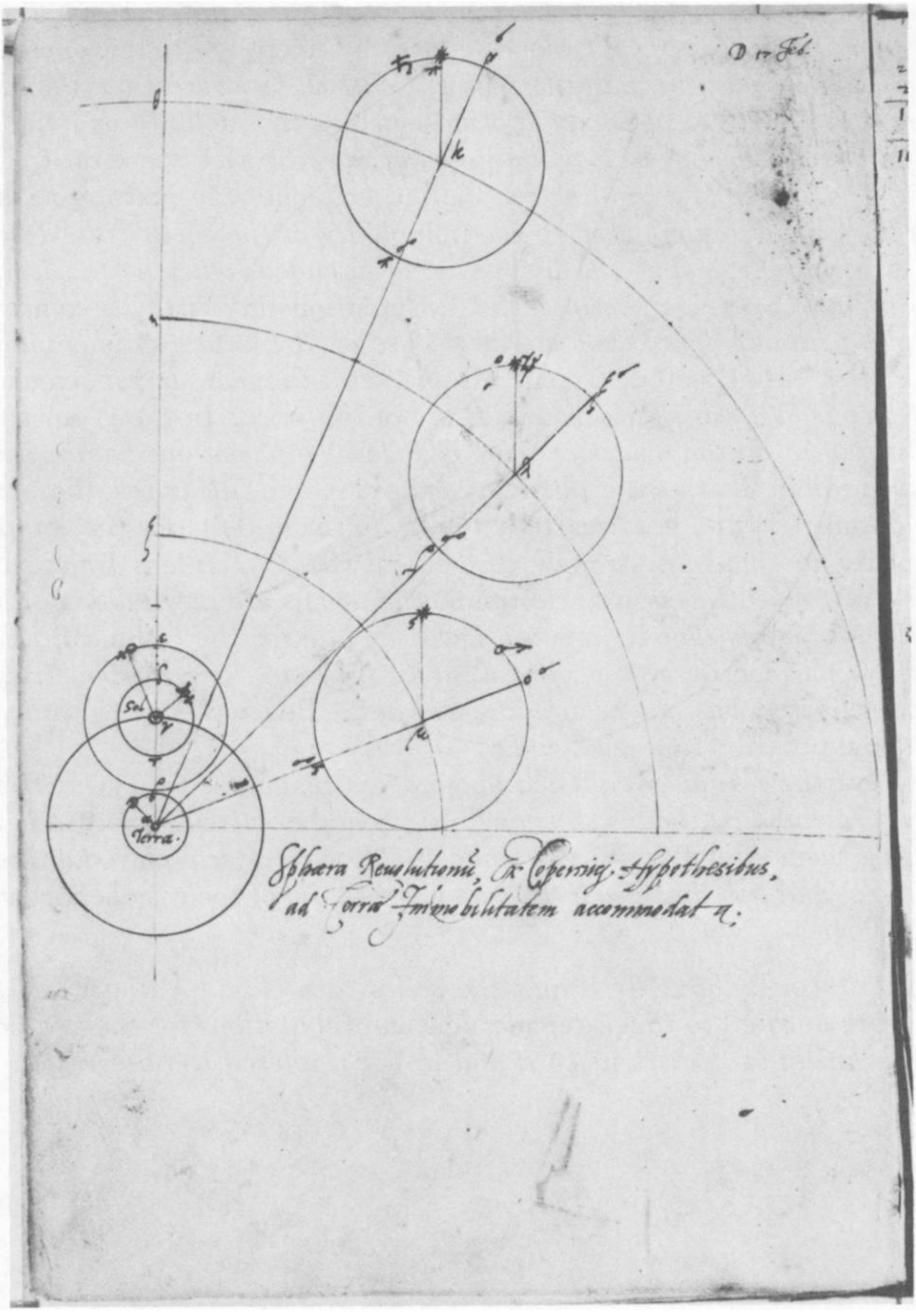

D 17 Feb.
k
Sol
Terra.
Sphæra Reuolutionū, Ex Copernici Hypothesibus,
ad Terræ Immobilitatem accommodata.

Fig. 44. Vatican f. 210v, Wittich's combined Sphere of Revolutions.

We note in passing that Wittich made an unlabeled and incomplete trial of this drawing, in a horizontal format, in the Liège volume.

In what sense can this diagram be said to exhibit the hypotheses of Copernicus? We recall (our discussion on page 82) that Copernicus used "hypothesis" in multiple senses. Wittich is aware that the word sometimes refers to basic assumptions such as the mobility or immobility of the earth, and in fact, he uses hypothesi *in this sense on f. 208v (our p. 132). In the heading for the present folio, the juxtaposition of the phrase "accommodated to the immobility of the earth" can deceive us into supposing that the first sense is intended, whereas the lack of any of the Copernican cosmological assumptions in Wittich's combined diagram should signal that another sense of "hypotheses" is employed here. Not only does Copernicus use the word to mean "arrangements," but this is Wittich's most common use of the word. In the geometrical arrangement on the diagram, there is a clear emphasis on the directions of the radii in the superior planetary epicycles, and their sizes; these visible parameters are, however, only the tip of the iceberg, for the complex epicyclet mechanisms strongly associated with Copernicus by the majority of sixteenth-century celestial mechanicians are now hidden on the preceding pages. The foundation has been laid for the technical details of a geoheliocentric system, but a major problem, the interpenetration of the spheres, has not been addressed here. Hence the series came, at least temporarily, to a dead end.*

Nevertheless, since Wittich showed his diagrams to Tycho Brahe (who remembered them well enough to try and eventually succeed in acquiring them after Wittich's death in 1586), they clearly played a role in Tycho's (and possibly also in Ursus') formulation of their geoheliocentric cosmologies.

Final note: *Folio 210v brings the series to a close. Vatican ff. 211–211v are devoted to rough calculations and tabulations for the positions of first-magnitude stars in 1578 and in 1580, related to observations of Spica in 1578.*

Acknowledgment: *While we are responsible for any flaws remaining in this appendix, we are very grateful to David Pingree and especially Noel Swerdlow for critical readings that have substantially strengthened parts of the text and commentary.*

Appendix II

Wittich's Obituary in *Silesia togata*

Two manuscript copies of Nicholas Henel's *Silesia togata* are found in the Wroclaw University Library, and each contains the encomium of Wittich twice (MS R 571, pp. 21–24 and 451–53; MS IV.F.127, ff. 415–16v and 641–42). This duplication together with the variant readings ranging from the spelling of Wittich's name (Wittichius, Vittichius, Wittigius) to details of punctuation suggests that none of the copies is outstandingly authoritative. We have generally followed R 571, pp. 451–53.[1]

Silesia Togata

Pulchrum fuit Paulo Wittichio Wratislaviensi ex illa Patria oriri, qua vix ullam nobiliorem sibi arrogare quispiam audeat. Pulchrius autem longe acri quodam mentis vigore, laboreque indefesso eo usque in Mathematicis scientiis, in quibus aliquo saltem usque progredi cum voluptati esse summae, tum gloriae sempiternae Peripaticorum princeps adfirmavit, processisse: ut paucos inter συγχρόνους habuerit, qui palmam ipsi ambiguam fecerint, pauciores vero, si tamen ulli, qui praeripuerint. Quae quidem viri clarissimi laus tanto major: quanto jucundius, imo divinius studium, mundi cum aetherei tum elementarii secreta mirari, ac siderum cumprimis cursus, orbes, aspectus contemplatione adsequi: ut in omnibus auctorem DEUM tot operum miraculo veneremur: si praesertim intra cancellos consistentes, ne haec superum affectata notitia, nimis curiosis nec licitis quaestionibus nos inlaqueet, sedulo caveamus. Fecit id indubie noster hic: nec Altum TEMERE minus, quam SAPERE didicit[2]: cum e contra plusculos videamus, nimio coeli (a quo tam longe absunt) studio, ad criticos mores, et illaudata flexisse. A praelustribus illis Patriae decoribus Andrea Dudithio, Johanne Cratore, Nicolao Rhedingero [sic], Martino Schillingio, aliis ob ingenii praestantiam virtutemque in pretio atque aestimatione habitus, cum in aulam inde concessisset Caesaream ibidemque summos pariter viros, fautores ac Patronos reperisset haud ita diu superstes Viennae Austriorum, quinto Eidus Januarias Anno Salutis supra mille quingentos sexto et octuagesimo, funesto Principibus, infesto doctis, humano carcere liberatus ad coelum evolvit: morte quidem si non immatura, certe vel ideo lugenda, quod eruditis accuratisque lucubrationibus reipublicae literariae carendum est; quas ab eo partim adfectas, partim etiam perfectas, si heredum incuria luci non invidesset, haberet utique Wratislavia, cur Regiomontio Johannem Mollerum, Torunio Nicolaum Copernicum, Feldkirchio Georgium Joachimum Rheticum, Carolostadio Johannem Schonerum, Leisnicae Petrum Apianum, Ingelhemio Sebastianum Munsterum, Ingolstadio Philippum Appianum, Leonhovitio Johannem Stadium, aliis alios invidere desineret, quorum monumenta reconditae doctrinae plena orbis terrarum nunc admiratur. Felix tamen hac parte post obitum Wittichius: quod encomiasten consecutus est illum ipsum, quem dixi Nicolaum Rhedigerum a Strisa, virum inter doctos nobilissimum, inter nobiles doctissimum, inter utrosque optimum, inter omnes modestissimum, qui Epitaphio Epigrammate τόν μακαρίτην prosequutus est hujusmodi:

---

[1] We thank Harvard undergraduates Scott Feira and Joanna Bench for making preliminary translations.

[2] Alain Segonds has pointed out that this is a play on the words of Romans:11:20b, "noli altum sapere, sed time." See "L'alto e il basso" in Carlo Ginzburg, *Miti Emblemi Spie* (Nuovo Politecnico 152, Torin, 1986).

Heic situs est, primas quem Bresla in luminis oras
  Extulit optato sidere WITTICHIUS
Cui terrae occultae latebrae caecique recessus
  Unicaque aethereae cura fuere faces
Coetera sordebant: Et fama quoque ipsa. Sed istam
  Nunc etiam invitus, quam fugiebat, habet
Frustra ergo extinctum querimur, cui posthuma servant
  Astra animam, famam scripta, cadaver humus.

Casparis Conradi tale legitur in eundem distichon

Sidera Wittichius permensus humumque jacontem
Sidera nunc animo, corpore servat humum.[3]

Silesian Men of Distinction

It was fortunate for Paul Wittich of Wratislavia to have come from that homeland, for scarcely anyone would dare claim his own as more noble. But it was more admirable by far that he progressed with a certain sharp vigor of mind and indefatigable labor in mathematical sciences, in which the Prince of Peripatetics [Aristotle] has asserted that to advance even a little brings not only the greatest satisfaction but also eternal glory. Indeed, few among his contemporaries would have been in a state to compete with him for the prize, and even fewer—if any at all—would have been able to snatch it away. And surely the praise of that illustrious man is all the greater, for it is more pleasing and a more divine endeavor to wonder at the secrets of both the ethereal and the elemental world, and to contemplate the stars in their courses, their orbs and their appearances, so that we might worship God the creator of all things and so many marvelous works, but above all standing fast within His statutes. May we zealously guard lest the pursuit of knowledge entrap us with excessive curiosity or impermissible questions. Our man unquestionably did so: he taught to Fear no less than to Know what is Above, when elsewhere we see others who have been turned to critical and wicked ways by too much study of the heavens (from which they are so far removed).

---

[3] Note the similarity to Kepler's epitaph, "Mensus eram coelos, nunc terrae metior umbras. Mens coelestis erat, corporis umbra jacet."

He was held in high esteem by those outstanding and notable men of his native land, Andreas Dudith, Johannes Crato, Nicholas Rhediger, Martin Schilling, and others, on account of his excellence and virtuous character. When he went forth from here to the Imperial Court, he also found great men, protectors, and patrons, but he did not survive long in Vienna of the Austrians: five days before the Ides of January, 1586, lamented by Princes and grieved by the learned, his spirit was freed from this human prison and flew to Heaven. His death, even if not premature, is very surely woeful, for it deprived the republic of letters of his learned and accurate researches, partly well under way and partly completed by him. If the carelessness of his heirs had not deprived these writings of publication, Wroclaw would not have to envy Koenigsberg with its Johann Müller [Regiomontanus], Torun with its Nicholas Copernicus, Feldkirch with its Georg Joachim Rheticus, Karlstadt with its Johannes Schöner, Leisnig with its Peter Apianus, Ingelheim with its Sebastian Münster, Ingolstadt with its Philipp Apianus, Leonhout with its Johannes Stadius, and those at other places whose works, full of recondite teachings, are now admired throughout the whole world.

Wittich nevertheless was fortunate after death to have as his eulogist the aforementioned Nicholas Rhediger of Strisa, a man most noble among the learned, most learned among the noble, the best among both and the most modest among all, who honored the memory of the departed man with this epigrammatic epitaph:

> Here lies Wittich, who first saw the light in Breslau,
> His lucky star.
> The secret lands and hiding places of the heavens
> Have been torches for him.
> He cared little for some things, even fame itself.
> But now the fame that he fled is unwillingly his.
> Thus lamented is his death; now the stars claim his spirit,
> Writings preserve his fame, the ground holds his body.

This couplet by Caspar Conrad was also written about him:

> Wittich, after having measured the stars and the ground, now watches over the stars with his mind, the ground with his body.

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